Prentice Hall SCIENCE

Annotated Teacher's Edition

# Electricity and Magnetism

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The new Prentice Hall Science program consists of 19 hardcover books, each of which covers a particular area of science. All of the sciences are represented in the program so you can choose the perfect fit to *your* particular curriculum needs.

The flexibility of this program will allow you to teach those topics you want to teach, and to teach them *in-depth*. Virtually any approach to science—general, integrated, coordinated, thematic, etc.—is possible with Prentice Hall Science.

Above all, the program is designed to make your teaching experience easier and more fun.

PRENTICE HALL SCIENCE

**ELECTRICITY AND MAGNETISM**
- Ch. 1. Electric Charges and Currents
- Ch. 2. Magnetism
- Ch. 3. Electromagnetism
- Ch. 4. Electronics and Computers


**HEREDITY: THE CODE OF LIFE**
- Ch. 1. What is Genetics?
- Ch. 2. How Chromosomes Work
- Ch. 3. Human Genetics
- Ch. 4. Applied Genetics


**ECOLOGY: EARTH'S LIVING RESOURCES**
- Ch. 1. Interactions Among Living Things
- Ch. 2. Cycles in Nature
- Ch. 3. Exploring Earth's Biomes
- Ch. 4. Wildlife Conservation

**PARADE OF LIFE: MONERANS, PROTISTS, FUNGI, AND PLANTS**
- Ch. 1. Classification of Living Things
- Ch. 2. Viruses and Monerans
- Ch. 3. Protists
- Ch. 4. Fungi
- Ch. 5. Plants Without Seeds
- Ch. 6. Plants With Seeds

**EXPLORING THE UNIVERSE**
- Ch. 1. Stars and Galaxies
- Ch. 2. The Solar System
- Ch. 3. Earth and Its Moon


**EVOLUTION: CHANGE OVER TIME**
- Ch. 1. Earth's History in Fossils
- Ch. 2. Changes in Living Things Over Time
- Ch. 3. The Path to Modern Humans


**EXPLORING EARTH'S WEATHER**
- Ch. 1. What Is Weather?
- Ch. 2. What Is Climate?
- Ch. 3. Climate in the United States

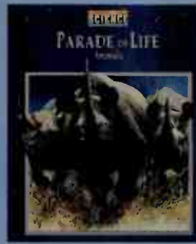
**THE NATURE OF SCIENCE**
- Ch. 1. What is Science?
- Ch. 2. Measurement and the Sciences
- Ch. 3. Tools and the Sciences


**ECOLOGY: EARTH'S NATURAL RESOURCES**

Ch. 1. Energy Resources
Ch. 2. Earth's Nonliving Resources
Ch. 3. Pollution
Ch. 4. Conserving Earth's Resources

**MOTION, FORCES, AND ENERGY**

Ch. 1. What Is Motion?
Ch. 2. The Nature of Forces
Ch. 3. Forces in Fluids
Ch. 4. Work, Power, and Simple Machines
Ch. 5. Energy: Forms and Changes



**PARADE OF LIFE: ANIMALS**

Ch. 1. Sponges, Cnidarians, Worms, and Mollusks
Ch. 2. Arthropods and Echinoderms
Ch. 3. Fish and Amphibians
Ch. 4. Reptiles and Birds
Ch. 5. Mammals


**CELLS: BUILDING BLOCKS OF LIFE**

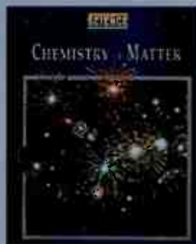
Ch. 1. The Nature of LIfe
Ch. 2. Cell Structure and Function
Ch. 3. Cell Processes
Ch. 4. Cell Energy


**DYNAMIC EARTH**

Ch. 1. Movement of the Earth's Crust
Ch. 2. Earthquakes and Volcanoes
Ch. 3. Plate Tectonics
Ch. 4. Rocks and Minerals
Ch. 5. Weathering and Soil Formation
Ch. 6. Erosion and Deposition

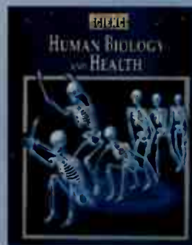

**MATTER: BUILDING BLOCK OF THE UNIVERSE**

Ch. 1. General Properties of Matter
Ch. 2. Physical and Chemical Changes
Ch. 3. Mixtures, Elements, and Compounds
Ch. 4. Atoms: Building Blocks of Matter
Ch. 5. Classification of Elements: The Periodic Table



**CHEMISTRY OF MATTER**

Ch. 1. Atoms and Bonding
Ch. 2. Chemical Reactions
Ch. 3. Families of Chemical Compounds
Ch. 4. Chemical Technology
Ch. 5. Radioactive Elements

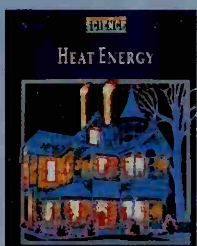


**HUMAN BIOLOGY AND HEALTH**

Ch. 1. The Human Body
Ch. 2. Skeletal and Muscular Systems
Ch. 3. Digestive System
Ch. 4. Circulatory System
Ch. 5. Respiratory and Excretory Systems
Ch. 6. Nervous and Endocrine Systems
Ch. 7. Reproduction and Development
Ch. 8. Immune System
Ch. 9. Alcohol, Tobacco, and Drugs

**EXPLORING PLANET EARTH**

Ch. 1. Earth's Atmosphere
Ch. 2. Earth's Oceans
Ch. 3. Earth's Fresh Water
Ch. 4. Earth's Landmasses
Ch. 5. Earth's Interior




**HEAT ENERGY**

Ch. 1. What Is Heat?
Ch. 2. Uses of Heat

**SOUND AND LIGHT**

Ch. 1. Characteristics of Waves
Ch. 2. Sound and Its Uses
Ch. 3. Light and the Electromagnetic Spectrum
Ch. 4. Light and Its Uses

# A COMPLETELY INTEGRATED LEARNING SYSTEM...

The Prentice Hall Science program is an *integrated* learning system with a variety of print materials and multimedia components. All are designed to meet the needs of diverse learning styles and your technology needs.

### THE STUDENT BOOK

Each book is a model of **excellent writing and dynamic visuals**—designed to be exciting and motivating to the student *and* the teacher, with relevant examples integrated throughout, and more opportunities for many different activities which apply to everyday life.

**Problem-solving activities** emphasize the thinking process, so problems may be more open-ended.

**"Discovery Activities"** throughout the book foster active learning.

**Different sciences, and other disciplines, are integrated throughout** the text and reinforced in the "Connections" features (the connections between computers and viruses is one example).

### TEACHER'S RESOURCE PACKAGE

In addition to the student book, the complete teaching package contains:

### ANNOTATED TEACHER'S EDITION

Designed to provide **"teacher-friendly" support** regardless of instructional approach:

- **Help is readily available** if you choose to teach thematically, to integrate the sciences, and/or to integrate the sciences with other curriculum areas.
- **Activity-based learning** is easy to implement through the use of Discovery Strategies, Activity Suggestions, and Teacher Demonstrations.
- Integration of all components is part of the teaching strategies.
- For instant accessibility, all of the teaching suggestions are wrapped around the student pages to which they refer.

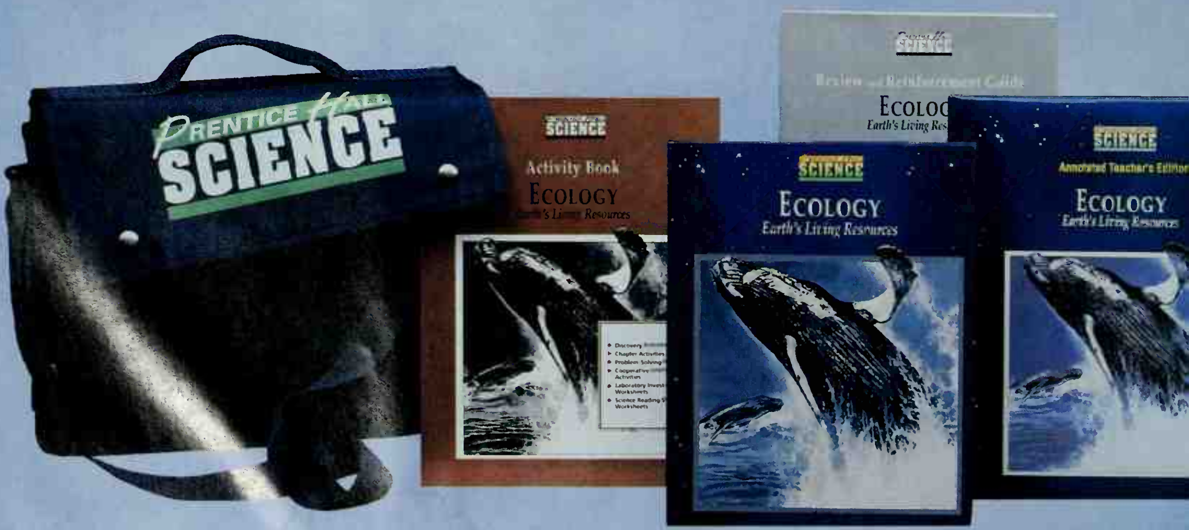
### ACTIVITY BOOK

Includes a **discovery activity for each chapter,** plus other activities including problem-solving and cooperative-learning activities.

### THE REVIEW AND REINFORCEMENT GUIDE

Addresses **students' different learning styles** in a clear and comprehensive format:

- Highly visual for visual learners.




TEACHER'S RESOURCE PACKAGE

# FOR THE PERFECT FIT TO YOUR TEACHING NEEDS.

- Can be used in conjunction with the program's audiotapes for auditory and language learners.
- More than a study guide, it's a guide to comprehension, with activities, key concepts, and vocabulary.

**ENGLISH AND SPANISH AUDIOTAPES**
Correlate with the Review and Reinforcement Guide to aid auditory learners.

**LABORATORY MANUAL ANNOTATED TEACHER'S EDITION**
**Offers at least one additional hands-on opportunity per chapter with** answers and teaching suggestions on lab preparation and safety.

**TEST BOOK**
Contains **traditional and up-to-the-minute strategies for student assessment.** Choose from performance-based tests in addition to traditional chapter tests and computer test bank questions.

**STUDENT LABORATORY MANUAL**
Each of the 19 books also comes with its own Student Lab Manual.



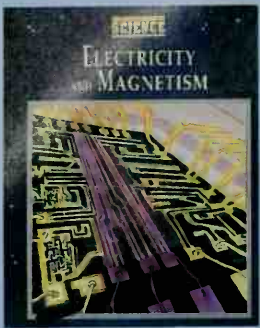
**ALSO INCLUDED IN THE INTEGRATED LEARNING SYSTEM:**

- Teacher's Desk Reference
- English Guide for Language Learners
- Spanish Guide for Language Learners
- Product Testing Activities
- Transparencies
- Computer Test Bank (IBM, Apple, or MAC)
- VHS Videos
- Videodiscs
- Interactive Videodiscs (Level III)
- Courseware

All components are integrated in the teaching strategies in the Annotated Teacher's Edition, where they directly relate to the science content.

# THE PRENTICE HALL SCIENCE INTEGRATED LEARNING SYSTEM

The following components are integrated in the teaching strategies for ELECTRICITY AND MAGNETISM.




- **Spanish Audiotape English Audiotape**
- **Activity Book**
- **Review and Reinforcement Guide**
- **Test Book—**including Performance-Based Tests
- **Laboratory Manual, Annotated Teacher's Edition**
- **Laboratory Manual**
- **English Guide for Language Learners**
- **Spanish Guide for Language Learners**
- **Transparencies:**
  Series and Parallel Circuits
- **Videos:**
  Electric Currents and Circuits
  Electricity and Magnetism
- **Interactive Videodiscs:**
  Invention: Mastering Sound

## INTEGRATING OTHER SCIENCES

Many of the other 18 Prentice Hall Science books can be integrated into **ELECTRICITY AND MAGNETISM.** The books you will find suggested most often in the Annotated Teacher's Edition are: MATTER: BUILDING BLOCK OF THE UNIVERSE; MOTION, FORCES, AND ENERGY; CHEMISTRY OF MATTER; EXPLORING EARTH'S WEATHER; HEAT ENERGY; HUMAN BIOLOGY AND HEALTH; PARADE OF LIFE: ANIMALS; ECOLOGY: EARTH'S NATURAL RESOURCES; EXPLORING THE UNIVERSE; THE NATURE OF SCIENCE; EXPLORING PLANET EARTH; SOUND AND LIGHT; and DYNAMIC EARTH.

## INTEGRATING THEMES

Many themes can be integrated into **ELECTRICITY AND MAGNETISM.** Following are the ones most commonly suggested in the Annotated Teacher's Edition: ENERGY, SCALE AND STRUCTURE, SYSTEMS AND INTERACTIONS, and STABILITY.

For more detailed information on teaching thematically and integrating the sciences, see the Teacher's Desk Reference and teaching strategies throughout the Annotated Teacher's Edition.

**For more information, call 1-800-848-9500 or write:**

PRENTICE HALL

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Annotated Teacher's Edition

# Prentice Hall Science

# Electricity and Magnetism

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# Contents of Annotated Teacher's Edition

# To the Teacher

Welcome to the *Prentice Hall Science* program. *Prentice Hall Science* has been designed as a complete program for use with middle school or junior high school science students. The program covers all relevant areas of science and has been developed with the flexibility to meet virtually all your curriculum needs. In addition, the program has been designed to better enable you—the classroom teacher—to integrate various disciplines of science into your daily lessons, as well as to enhance the thematic teaching of science.

The *Prentice Hall Science* program consists of nineteen books, each of which covers a particular topic area. The nineteen books in the *Prentice Hall Science* program are

The Nature of Science
Parade of Life: Monerans, Protists, Fungi, and Plants
Parade of Life: Animals
Cells: Building Blocks of Life
Heredity: The Code of Life
Evolution: Change Over Time
Ecology: Earth's Living Resources
Human Biology and Health
Exploring Planet Earth
Dynamic Earth
Exploring Earth's Weather
Ecology: Earth's Natural Resources
Exploring the Universe
Matter: Building Block of the Universe
Chemistry of Matter
Electricity and Magnetism
Heat Energy
Sound and Light
Motion, Forces, and Energy

Each of the student editions listed above also comes with a complete set of teaching materials and student ancillary materials. Furthermore, videos, interactive videos and science courseware are available for the *Prentice Hall Science* program. This combination of student texts and ancillaries, teacher materials, and multimedia products makes up your complete *Prentice Hall Science* Learning System.

# About the Teacher's Desk Reference

When you purchase a textbook in the *Prentice Hall Science* program, you also receive a copy of the *Teacher's Desk Reference.* The *Teacher's Desk Reference* includes all the standard information you need to know about *Prentice Hall Science.*

The *Teacher's Desk Reference* presents an overview of the program, including a full description of each ancillary available in the program. It gives a brief summary of each of the student textbooks available in the *Prentice Hall Science* Learning System. The *Teacher's Desk Reference* also demonstrates how the seven science themes incorporated into *Prentice Hall Science* are woven throughout the entire program.

In addition, the *Teacher's Desk Reference* presents a detailed discussion of the features of the Student Edition and the features of the Annotated Teacher's Edition, as well as an overview section that summarizes issues in science education and offers a message about teaching special students. Selected instructional essays in the *Teacher's Desk Reference* include English as a Second Language (ESL), Multicultural Teaching, Cooperative-Learning Strategies, and Integrated Science Teaching, in addition to other relevant topics. Further, a discussion of the Multimedia components that are part of *Prentice Hall Science,* as well as how they can be integrated with the textbooks, is included in the *Teacher's Desk Reference.*

The *Teacher's Desk Reference* also contains in blackline master form a booklet on Teaching Graphing Skills, which may be reproduced for student use.

# Integrating the Sciences

The *Prentice Hall Science* Learning System has been designed to allow you to teach science from an integrated point of view. Great care has been taken to integrate other science disciplines, where appropriate, into the chapter content and visuals. In addition, the integration of other disciplines such as social studies and literature has been incorporated into each textbook.

On the reduced student pages throughout your Annotated Teacher's Edition you will find numbers within blue bullets beside selected passages and visuals. An Annotation Key in the wraparound margins indicates the particular branch of science or other discipline that has been integrated into the student text. In addition, where appropriate, the name of the textbook and the chapter number in which the particular topic is discussed in greater detail is provided. This enables you to further integrate a particular science topic by using the complete *Prentice Hall Science* Learning System.

# Thematic Overview

When teaching any science topic, you may want to focus your lessons around the underlying themes that pertain to all areas of science. These underlying themes are the framework from which all science can be constructed and taught. The seven underlying themes incorporated into *Prentice Hall Science* are

Energy
Evolution
Patterns of Change
Scale and Structure
Systems and Interactions
Unity and Diversity
Stability

A detailed discussion of each of these themes and how they are incorporated into the *Prentice Hall Science* program are included in your *Teacher's Desk Reference.* In addition, the *Teacher's Desk Reference* includes thematic matrices for the *Prentice Hall Science* program.

A thematic matrix for each chapter in this textbook follows. Each thematic matrix is designed with the list of themes along the left-hand column and in the right-hand column a big idea, or overarching concept statement, as to how that particular theme is taught in the chapter.

The primary themes in this textbook are Energy, Scale and Structure, Systems and Interactions, and Stability. Primary themes throughout *Prentice Hall Science* are denoted by an asterisk.

# CHAPTER 1

## *Electric Charges and Currents*

| | |
|---|---|
| ***ENERGY** | • Energy is required to make electric charges leave their atoms and move.<br>• Additional energy, in the form of a potential difference, is required to make electric charges continue flowing once they have begun. |
| **EVOLUTION** | |
| **PATTERNS OF CHANGE** | • An object can acquire charge by friction, conduction, or induction. |
| ***SCALE AND STRUCTURE** | • No matter how large a current is, its source is always in the particles within the atoms that make up the conducting material. |
| ***SYSTEMS AND INTERACTIONS** | • The opposition to the movement of charge in a material is known as the resistance.<br>• The voltage divided by the resistance determines the amount of current in a material. |
| **UNITY AND DIVERSITY** | • Current is the rate at which charge flows through a conductor.<br>• Current may be direct, moving in only one direction, or alternating, changing direction repeatedly.<br>• A circuit provides a closed path for current. A circuit may be series or parallel. |
| ***STABILITY** | • Charge is neither created nor destroyed. It is merely transferred. |

# CHAPTER 2

## *Magnetism*

| | |
|---|---|
| ***ENERGY** | • Energy is required to overcome magnetic forces of attraction or repulsion. |
| **EVOLUTION** | • Changes in the Earth's magnetic field over time are recorded in the patterns of magnetic rocks.<br>• Some organisms have made adaptations to the Earth's magnetic field. |
| **PATTERNS OF CHANGE** | • The motion of a charged particle will be altered by the magnetic forces exerted in a magnetic field. |
| ***SCALE AND STRUCTURE** | • Objects as large as the Earth and the sun produce magnetic fields evident throughout the solar system. Yet the source of magnetism is in the atom—the building block of matter. |
| ***SYSTEMS AND INTERACTIONS** | • Like magnetic poles repel each other. Unlike magnetic poles attract each other.<br>• If two magnets are placed near each other, the magnetic field of each one will be affected by the other. |
| **UNITY AND DIVERSITY** | • The magnetic forces exerted by any magnet are strongest at the poles. One pole, however, exerts an attractive force and the other a repulsive force. |
| ***STABILITY** | • The magnetic lines of force of a magnet move in a complete circle from the north pole to the south pole. |

# CHAPTER 3

## *Electromagnetism*

| | |
|---|---|
| ***ENERGY** | • The principles of electromagnetism can be applied to convert one form of energy into another.<br>• Energy can be conserved by transmitting alternating current with the use of transformers. |
| **EVOLUTION** | |
| **PATTERNS OF CHANGE** | • An electric current flowing through a wire will create a magnetic field whose direction depends on the direction of the current.<br>• A changing magnetic field gives rise to an electric current. |
| ***SCALE AND STRUCTURE** | • Electric current is produced and used at low voltages, but it is most efficiently transmitted at high voltages.<br>• Transformers change the voltage of alternating current for practical use and distribution. |
| ***SYSTEMS AND INTERACTIONS** | • A magnetic field will exert a force on a wire carrying current. |
| **UNITY AND DIVERSITY** | • Electric motors and generators both use electromagnets to convert one form of energy into another.<br>• A motor converts electric energy into mechanical energy.<br>• A generator converts mechanical energy into electric energy. |
| ***STABILITY** | • A magnetic field will always exist around a current. |

# CHAPTER 4

## *Electronics and Computers*

| | |
|---|---|
| ***ENERGY** | • Electromagnetic waves can be used to carry information in the form of energy from one place to another. |
| **EVOLUTION** | • Electronics has undergone a rapid evolution from an era of vacuum tubes and large machinery to the development of integrated circuits and microcomputers. |
| **PATTERNS OF CHANGE** | • Sound and picture broadcasts are converted into electric signals and then placed on electromagnetic waves (radio waves) that are sent out through the air.<br>• Receivers convert the signals back into their original forms. |
| ***SCALE AND STRUCTURE** | • The future of computers is in the very large and very small.<br>• Microprocessors can hold the entire processing capability on one small chip.<br>• Groups of computers are being linked together to form supercomputers. |
| ***SYSTEMS AND INTERACTIONS** | • The release, behavior, and control of electrons constitutes the foundation of electronics. |
| **UNITY AND DIVERSITY** | • Diodes and transistors usually play different roles in an electronic device.<br>• Diodes serve as a one-way path for current. Transistors amplify current. But both have been essential to the development of modern electronics. |
| ***STABILITY** | • Radio waves used in radio communication all travel at the same speed. |

# Comprehensive List of Laboratory Materials

| Item | Quantities per Group | Chapter |
|---|---|---|
| Aluminum foil | 1 small sheet | 3 |
| Abacus | 1 | 4 |
| Box, cardboard, to fit compass | 1 | 1 |
| Coins | | |
| nickel | 1 | 3 |
| dime | 1 | 1, 3 |
| penny | 2 | 1 |
| Compass | 1 | 1, 2 |
| Copper sheet (or penny) | 1 | 3 |
| Dry cell | 1 | 3 |
| Lemon | 1 | 1 |
| Magnet | | |
| bar | 1 | 2 |
| horseshoe | 1 | 2 |
| Nails, 10 cm long | 5 | 3 |
| Paper clips | 6 | 3 |
| Sandpaper | 1 | 1 |
| Scissors | 1 | 1 |
| Wire | | |
| bell, 2 m | 1 | 3 |
| bell, 150 cm | 1 | 1 |

*Prentice Hall Science*

# Electricity and Magnetism

**Student Text and Annotated Teacher's Edition**
**Laboratory Manual**
**Teacher's Resource Package**
**Teacher's Desk Reference**
**Computer Test Bank**
**Teaching Transparencies**
**Science Reader**
**Product Testing Activities**
**Computer Courseware**
**Video and Interactive Video**

The illustration on the cover, rendered by Keith Kasnot, shows an integrated circuit board used in computers and many other electronic devices.

Credits begin on page 129.

FIRST EDITION



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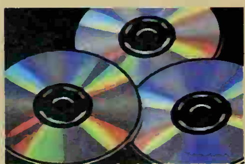
# CONTENTS

## ELECTRICITY AND MAGNETISM



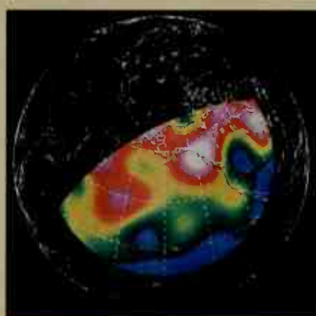


## Reference Section



## Features





# CONCEPT MAPPING

Throughout your study of science, you will learn a variety of terms, facts, figures, and concepts. Each new topic you encounter will provide its own collection of words and ideas—which, at times, you may think seem endless. But each of the ideas within a particular topic is related in some way to the others. No concept in science is isolated. Thus it will help you to understand the topic if you see the whole picture; that is, the interconnectedness of all the individual terms and ideas. This is a much more effective and satisfying way of learning than memorizing separate facts.

Actually, this should be a rather familiar process for you. Although you may not think about it in this way, you analyze many of the elements in your daily life by looking for relationships or connections. For example, when you look at a collection of flowers, you may divide them into groups: roses, carnations, and daisies. You may then associate colors with these flowers: red, pink, and white. The general topic is flowers. The subtopic is types of flowers. And the colors are specific terms that describe flowers. A topic makes more sense and is more easily understood if you understand how it is broken down into individual ideas and how these ideas are related to one another and to the entire topic.

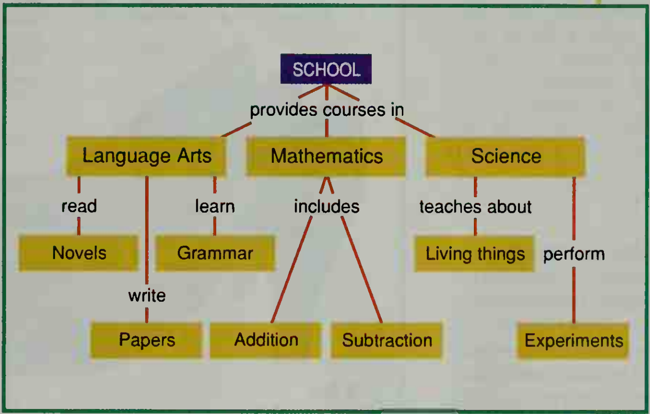
It is often helpful to organize information visually so that you can see how it all fits together. One technique for describing related ideas is called a **concept map**. In a concept map, an idea is represented by a word or phrase enclosed in a box. There are several ideas in any concept map. A connection between two ideas is made with a line. A word or two that describes the connection is written on or near the line. The general topic is located at the top of the map. That topic is then broken down into subtopics, or more specific ideas, by branching lines. The most specific topics are located at the bottom of the map.

To construct a concept map, first identify the important ideas or key terms in the chapter or section. Do not try to include too much information. Use your judgment as to what is really important. Write the general topic at the top of your map. Let's use an example to help illustrate this process. Suppose you decide that the key terms in a section you are reading are School, Living Things, Language Arts, Subtraction, Grammar, Mathematics, Experiments, Papers, Science, Addition, Novels. The general topic is School. Write and enclose this word in a box at the top of your map.

SCHOOL

Now choose the subtopics—Language Arts, Science, Mathematics. Figure out how they are related to the topic. Add these words to your map. Continue this procedure until you have included all the important ideas and terms. Then use lines to make the appropriate connections between ideas and terms. Don't forget to write a word or two on or near the connecting line to describe the nature of the connection.

Do not be concerned if you have to redraw your map (perhaps several times!) before you show all the important connections clearly. If, for example, you write papers for Science as well as for Language Arts, you may want to place these two subjects next to each other so that the lines do not overlap.




One more thing you should know about concept mapping: Concepts can be correctly mapped in many different ways. In fact, it is unlikely that any two people will draw identical concept maps for a complex topic. Thus there is no one correct concept map for any topic! Even though your concept map may not match those of your classmates, it will be correct as long as it shows the most important concepts and the clear relationships among them. Your concept map will also be correct if it has meaning to you and if it helps you understand the material you are reading. A concept map should be so clear that if some of the terms are erased, the missing terms could easily be filled in by following the logic of the concept map.

# *Electricity and Magnetism*

## TEXT OVERVIEW

In this textbook students are introduced to electricity. Electric charge is explained on the basis of atomic structure, and static electricity is discussed. Students also learn about voltage, current, and resistance as well as electrochemical cells. They gain a practical understanding of electric power as utility and learn about the safe use of electricity.

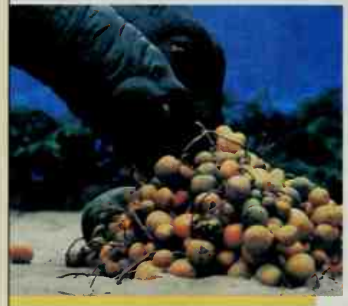
Next, students study magnetism and magnetic poles, fields, lines of force, and domains. They learn about Earth's magnetic properties and compasses. They also relate magnetism to Van Allen radiation belts and the aurora as well as to the study of astronomy and applications in nuclear fusion.

Students study electromagnetism and electromagnetic induction, and they identify practical applications of these concepts. Finally, students read about electronic devices, including vacuum tubes, transistors, and integrated circuits. The operations of radios and televisions are described next. Students also learn about the development and operation of computers.

## TEXT OBJECTIVES

1. Describe the forces between electric charges and the atomic basis of electric charges.
2. Identify the effects of static electricity.
3. Define voltage, current, and resistance and apply these concepts to circuit situations.

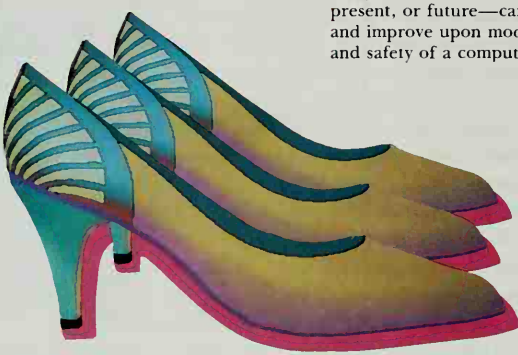
# ELECTRICITY AND MAGNETISM



*As if made of flesh and blood, these computer-controlled dinosaurs appear to be munching on assorted fruits.*

Huge dinosaurs roar wildly as they tower ove your head. Some cause the ground to tremble m by walking past you. Have you been transported back in time? No. You are at Epcot Center in W Disney World where animated creatures are desi and controlled by computers.

Although this computer application is specific designed to amuse and entertain you, other computer applications have more scientific and infor tional uses. Researchers can enter available data into computers in order to build complete, movi models of subjects that can only be imagined—n observed. For example, computers have enabled scientists to design a wide range of new products simulate various aspects of prehistoric life, and hypothesize about the features of distant planets and galaxies. The beauty of such applications is t designers—whether they are interested in the pa present, or future—can build, experiment with, and improve upon models with the speed, accura and safety of a computer and its display devices.



*The design of many new products is aided by computers. In this way designers can observe a new product, such as this shoe, and test various features of the product before it is manufactured.*

8 ■ P

## INTRODUCING ELECTRICITY AND MAGNETISM

### USING THE TEXTBOOK

Begin your introduction of the textbook by having students examine the textbook-opening photographs and captions. Before students read the textbook introduction, ask them the following questions.

• **What do you see in the top photograph on page P8?** (A dinosaur.)

• **Is this dinosaur alive?** (No. It is a computer-operated mechanism.)

• **Why are the shoes shown at the bottom of the page?** (The shoes were designed and tested by computers.)

• **What is taking place in the photograph on page P9?** (A computer model of a car is being tested for aerodynamics.)

• **What do all the photographs have in common?** (The photographs illustrate computer applications in product design, testing, and operation.)

• **Based on your examination of the photographs, what role do you think computers play in modern life?** (Answers will vary, but students may reply that computers are involved in every facet of life from entertainment to the products and services we use.)

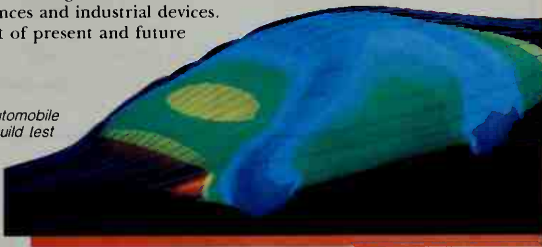
• **How do you think computers are related to electricity and magnetism?** (Answers will vary. Point out that computers

# CHAPTERS

1 Electric Charges and Currents
2 Magnetism
3 Electromagnetism
4 Electronics and Computers

Much of the technology that makes computer pplications possible is more familiar than you might hink. In this textbook you will discover that the henomona of electricity and magnetism reach far eyond household appliances and industrial devices. 'hey reach into the heart of present and future echnology.

*would be quite costly for automobile ianufacturers to constantly build test iodels of new cars. Instead, omputers enable designers ) create models on a creen. This computer model ; being tested for erodynamic efficiency.*



## Discovery Activity

### *Flying Through Air With the Greatest of Ease*

1. Inflate a balloon and tie the end.
2. Bring the balloon within centimeters of a plate filled with a mixture of salt and pepper. Observe for 3 to 5 minutes.
3. Take the balloon away from the plate. Rub the balloon with a piece of wool. Repeat step 2.
   - How is the behavior of the salt and pepper different before and after you rub the balloon with wool?
4. Arrange small piles of each of the following materials: paper clips, rubber bands, pieces of paper, assorted metal and plastic buttons. Make sure that each of the piles is separated from the others.
5. Hold a magnet above the first pile without touching it. Observe what happens. Repeat this procedure over each of the remaining piles.
   - What happens to each of the materials when you place the magnet above it? What can you conclude about how different materials are affected by a magnet?



and their applications are possible because of the technologies resulting from electricity and magnetism.)

### DISCOVERY ACTIVITY

**Flying Through Air With the Greatest of Ease**

Begin your introduction to the textbook by having students perform the Discovery Activity. In the activity students will discover the effects of static electricity on salt and pepper. They will also discover that magnets will pick up some items and not others. Ask students to hypothesize about ways in which static electricity and magnets are alike. Explain that in this textbook, they will learn about the similarities in the forces of electricity and magnetism. If some students have a basic knowledge about electricity and magnetism, ask them if there is any relationship between electricity and magnetism.

**4.** Describe the safe use of electricity.
**5.** Discuss magnetism and magnetic poles, fields, and domains.
**6.** Explain electromagnetism and electromagnetic induction and identify practical applications of these concepts.
**7.** Cite details about the use of electronic devices and computers.

### CHAPTER DESCRIPTIONS

**1 Electric Charges and Currents** In Chapter 1 the characteristics of electrical forces are explored. Electric charges are discussed in terms of atomic structure. Properties of static electricity are discussed, and concepts of currents are introduced. Electric circuits and safety devices such as fuses and circuit breakers are described. Finally, wattage is defined, and electric energy is related to time and power.

**2 Magnetism** Chapter 2 introduces concepts of magnetism, defining magnetic poles, fields, and domains. The magnetic properties of Earth are discussed, and the chapter explains that Earth's magnetic history is traced through magnetic stripes in molten rocks. Finally, the chapter examines magnetism in action in Earth's magnetosphere and the role of magnetism in scientific pursuits such as astronomy and nuclear fusion.

**3 Electromagnetism** In Chapter 3 the relationship between electricity and magnetism, known as electromagnetism, is explored. The experiments of Oersted illustrate that the direction of a magnetic field generated by an electric current depends on the electric current's direction. The electric motor and galvanometers are described, as are generators and transformers.

**4 Electronics and Computers** Chapter 4 introduces students to the world of electronics. The definition of electronics is given, and the application of electronics in everyday appliances is explored. The chapter discusses the use of electronics in radios and televisions. It then details information about computers and their development.

# Chapter 1 Electric Charges and Currents

| SECTION | LABORATORY INVESTIGATIONS AND DEMONSTRATIONS |
|---|---|
| **1–1 Electric Charge**<br>pages P12–P14 | **Teacher Edition**<br>Comparing Light Sources, p. P10d |
| **1–2 Static Electricity**<br>pages P15–P22 | **Laboratory Manual**<br>Conductors and Insulators |
| **1–3 The Flow of Electricity**<br>pages P22–P30 | **Teacher Edition**<br>Making a Battery, p. P10d |
| **1–4 Electric Circuits**<br>pages P31–P35 | **Student Edition**<br>Electricity From a Lemon, p. P40<br>**Laboratory Manual**<br>Building Electric Circuits |
| **1–5 Electric Power**<br>pages P35–P39 | |
| **Chapter Review**<br>pages P40–P43 | |

*All materials in the Chapter Planning Guide Grid are available as part of the Prentice Hall Science Learning System.

| OTHER ACTIVITIES | MULTIMEDIA |
|---|---|
| **Activity Book**<br>Chapter Discovery: Making an Electroscope<br>ACTIVITY: Electric Charge and Force<br>**Student Edition**<br>Find Out by Doing: Electric Forces, p. P13<br>**Review and Reinforcement Guide**<br>Section 1–1 | **English/Spanish Audiotapes**<br>Section 1–1 |
| **Activity Book**<br>ACTIVITY: A Giant Electroscope<br>**Student Edition**<br>Find Out by Doing: Balloon Electricity, p. P15<br>Find Out by Doing: Spark, Crackle, Move, p. P16<br>Find Out by Doing: Observing Static Electricity, p. P21<br>**Review and Reinforcement Guide**<br>Section 1–2 | **English/Spanish Audiotapes**<br>Section 1–2 |
| **Activity Book**<br>ACTIVITY: Producing Electricity<br>**Student Edition**<br>Find Out by Reading: Life on the Prairie, p. P25<br>Find Out by Calculating: Ohm's Law, p. P30<br>**Review and Reinforcement Guide**<br>Section 1–3 | **Courseware**<br>Voltage, Current, and Resistance (Supplemental)<br>**English/Spanish Audiotapes**<br>Section 1–3 |
| **Activity Book**<br>ACTIVITY: Electric Circuitry<br>ACTIVITY: Electricity From an Olive<br>**Review and Reinforcement Guide**<br>Section 1–4 | **Video**<br>Electric Currents and Circuits<br>**Transparency Binder**<br>Series and Parallel Circuits<br>**English/Spanish Audiotapes**<br>Section 1–4 |
| **Activity Book**<br>ACTIVITY: Emergency Power Sources<br>ACTIVITY: Electric Math<br>**Student Edition**<br>Find Out by Thinking: Power and Heat, p. P37<br>Find Out by Calculating: How Much Electricity Do You Use?, p. P38<br>**Review and Reinforcement Guide**<br>Section 1–5 | **English/Spanish Audiotapes**<br>Section 1–5 |
| **Test Book**<br>Chapter Test<br>Performance-Based Test | **Test Book**<br>Computer Test Bank Test |

# Chapter 1 Electric Charges and Currents

## CHAPTER OVERVIEW

Electricity plays a very important role in our lives. From the moment we wake up in the morning to the time we go to bed, we power our lives by electricity. Atoms are a combination of protons, neutrons, and electrons. The protons and electrons have opposite electrical charges. Electrons have much less mass than protons have and are outside the protons, making it easier for electrons to move. Electricity can be defined as the energy associated with electrons that move from one place to another.

Static electricity results from the buildup of electrical charges on objects. When an object loses or gains electrons, it has a static electric charge. The electric current in a wire is a constant flow of electrons. The flow of electrons through a wire is called current. Current is measured in amperes. Electrons flow in a wire due to an electromotive force called voltage. Opposition to the flow of electrons is called resistance. Resistance is measured in ohms.

Current electricity can be direct current (DC) or alternating current (AC). Direct current means that the movement of electrons is in one direction. Alternating current is movement of electrons that reverses its direction regularly.

## 1–1 ELECTRIC CHARGE

### THEMATIC FOCUS

The purpose of this section is to introduce students to protons, neutrons, and electrons, and the electric charges of these particles. Forces of attraction between unlike charges and forces of repulsion between like charges are then discussed.

The themes that can be focused on in this section are energy and stability.

***Energy:** Energy is required to make electric charges leave their atoms and move.

***Stability:** Charge is neither created nor destroyed. It is merely transferred.

### PERFORMANCE OBJECTIVES 1–1

**1. Name the three principal subatomic particles and state their charges.**
**2. Describe the nature of forces that act between unlike charges and like charges.**
**3. Define electric field.**

### SCIENCE TERMS 1–1

**atom p. P12**
**proton p. P12**
**neutron p. P12**
**electron p. P12**
**charge p. P12**
**force p. P13**
**electric field p. P14**

## 1–2 STATIC ELECTRICITY

### THEMATIC FOCUS

The purpose of this section is to introduce students to static electricity, which involves a buildup of charge. They also learn about three methods of electrically charging objects: friction, conduction, and induction. Conductors and insulators are described and contrasted. Lightning is then explained as a static electricity phenomenon involving electric discharge.

The themes that can be focused on in this section are systems and interactions and patterns of change.

***Systems and interactions:** The properties of the atoms of a substance determine whether it will conduct electricity well, poorly, or not at all.

**Patterns of change:** An object can acquire charge by friction, conduction, or induction.

### PERFORMANCE OBJECTIVES 1–2

**1. Define and explain static electricity.**
**2. Compare friction, conduction, and induction.**
**3. Explain the difference between insulators and conductors.**
**4. Explain what causes lightning.**
**5. Describe the structure and use of the electroscope.**

### SCIENCE TERMS 1–2

**friction p. P16**
**conduction p. P17**
**conductor p. P17**
**insulator p. P17**
**induction p. P18**
**static electricity p. P18**
**electric discharge p. P19**
**electroscope p. P21**

## 1–3 THE FLOW OF ELECTRICITY

### THEMATIC FOCUS

The purpose of this section is to introduce students to the concept of electric current. The concept of voltage, or potential difference, is introduced as a measure of the energy available to move electrons. Then, resistance is discussed, and resistance, voltage, and current are related through Ohm's law, $I = V/R$.

The themes that can be focused on in this section are unity and diversity and systems and interactions.

**Unity and diversity:** Current is the rate at which charge flows through a conductor. Current may be direct, moving in only one direction, or alternating, changing direction repeatedly.

***Systems and interactions:** The opposition to the movement of charge in a material is known as the resistance. The voltage divided by the resistance determines the amount of current in a material.

### PERFORMANCE OBJECTIVES 1–3

**1. Define electric current and state the unit in which it is measured.**
**2. Describe the structure and uses of dry cells and wet cells.**
**3. Define voltage, state the unit in which it is expressed, and name the device used to measure it.**
**4. Define resistance and state the unit in which it is measured.**
**5. State and apply Ohm's law.**
**6. Contrast direct current and alternating current.**

CIENCE TERMS 1–3

attery p. P23
otential difference p. P24
hermocouple p. P24
hotocell p. P24
ircuit p. P25
urrent p. P25
oltage p. P26
esistance p. P28
uperconductor p. P29
Ohm's law p. P29
irect current p. P30
lternating current p. P30

## -4 ELECTRIC CIRCUITS

HEMATIC FOCUS

The purpose of this section is to introuce students to the electric circuit—a omplete path for an electric current. Series circuits and parallel circuits are disussed and compared. Finally, safety deices such as the fuse and circuit breaker re described.

The themes that can be focused on in his section are unity and diversity and ystems and interactions.

**Unity and diversity:** A circuit proides a closed path for current. A circuit nay be series or parallel.

***Systems and interactions:** Fuses nd circuit breakers are safety devices hat interrupt the flow of current hrough a circuit so that wires will not verheat.

ERFORMANCE OBJECTIVES 1–4

**. Define electric circuit.**
**. State the parts of a circuit and their unctions.**
**. Compare series and parallel circuits.**
**. Explain the use and operation of uses and circuit breakers.**

CIENCE TERMS 1–4

eries circuit p. P32
arallel circuit p. P32
use p. P34
ircuit breaker p. P34

## 1–5 ELECTRIC POWER

THEMATIC FOCUS

The purpose of this section is to show students how the watt, the unit of electric power, is defined. Electric energy is then related to power and time by the equation $E = P \times t$, and the kilowatt-hour is introduced. Finally, important rules for electrical safety are presented.

The themes that can be focused on in this section are scale and structure and stability.

***Scale and structure:** No matter how large a current is, its source is always in the particles within the atoms that make up the conducting material.

***Stability:** Understanding the concepts of electricity will foster its proper and safe use.

PERFORMANCE OBJECTIVES 1–5

**1. Define electric power and state and apply the formula that relates it to voltage and current.**
**2. State the units of power and electric energy.**
**3. Calculate electric energy, given power and time.**
**4. State six important safety rules relating to electricity.**

SCIENCE TERMS 1–5

**power p. P35**

Discovery Learning

TEACHER DEMONSTRATIONS MODELING

### Comparing Light Sources

Place a table lamp and a flashlight on the demonstration table. Tell the class to watch and think about what happens during the demonstration.

Plug in the lamp and turn it on and off several times. Hold up the flashlight and turn it on and off several times. Discuss the demonstration using questions similar to the following.

- **How are the two electrical systems similar?** (Both systems use electricity, have bulbs, have a switch, and light/unlight the bulbs.)
- **How are the two electrical systems different?** (The table lamp uses regular 110-volt house current, whereas the flashlight uses a battery, or dry cell electricity. The table-lamp bulb was brighter and hotter than the flashlight bulb.)

### Making a Battery

You can make a simple battery by cutting 20 5-centimeter squares of zinc sheeting, of copper sheeting, and of blotting paper. Pile them on top of one another in this order: copper, blotting paper, zinc. A square of copper should be on the bottom and a square of zinc on the top. Tie the pile together with a thread.

Attach one wire to the top plate and one to the bottom. Immerse the entire pile in a solution of sodium bicarbonate. When the blotting paper is soaked, remove the pile.

Touch the free ends of the wires to a voltmeter to test the voltage. Ask students the following.

- **What is happening to produce a current?** (Electrons are flowing from the zinc end around to the copper end, and from each zinc inside to the copper below.)
- **What is the purpose of sodium-bicarbonate solution?** (It serves as an electrolyte, whose ions, or charged particles, conduct electricity.)

CHAPTER 1

# Electric Charges and Currents

## INTEGRATING SCIENCE

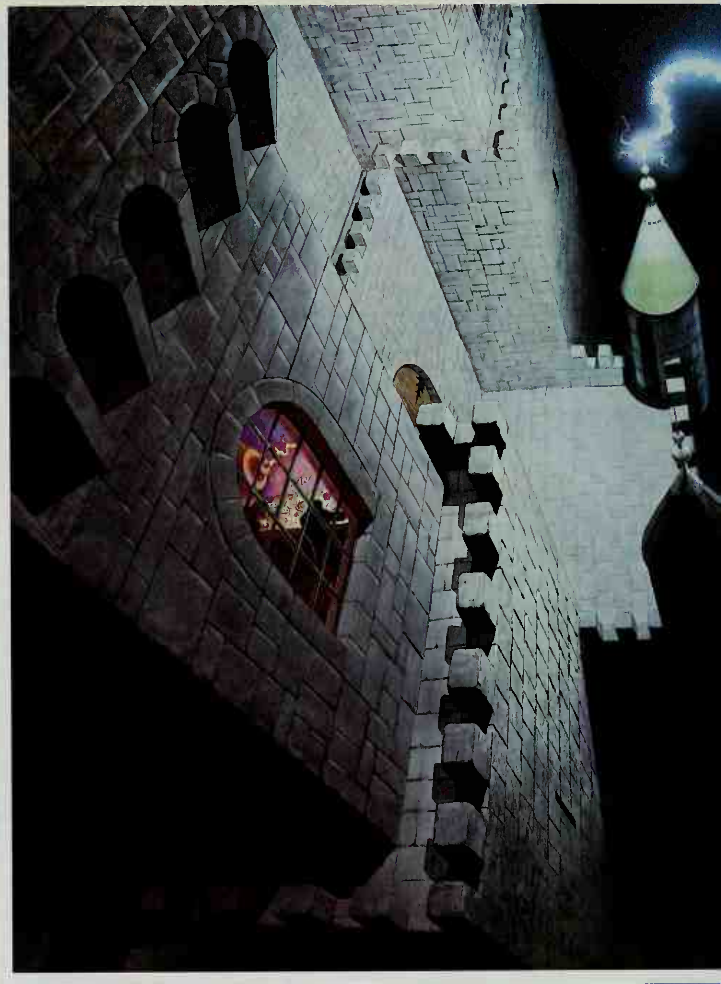
This physical science chapter provides you with numerous opportunities to integrate other areas of science, as well as other disciplines, into your curriculum. Blue numbered annotations on the student page and integration notes on the teacher wraparound pages alert you to areas of possible integration.

In this chapter you can integrate physical science and atoms (p. 12), physical science and force (p. 13), physical science and ions (p. 15), physical science and friction (p. 16), physical science and metals (pp. 17, 28), earth science and meteorology (p. 19), social studies (p. 20), physical science and work (p. 22), physical science and electrolytes (p. 23), physical science and heat (pp. 24, 28), language arts (p. 25), life science and muscles (p. 27), life science and zoology (p. 27), physical science and hydroelectric power (p. 29), mathematics (p. 30), physical science and power (p. 36), and life science and genetics (p. 39).

## SCIENCE, TECHNOLOGY AND SOCIETY/COOPERATIVE LEARNING

Electricity is a modern convenience that most of us would rather not have to live without! But, the cost of generating electricity is increasing both economically and environmentally. Most electricity is generated when power plants burn fossil fuels to produce steam. The steam then turns huge turbines to produce electricity that can be delivered to our homes. Fossil fuels are nonrenewable resources that are being consumed at an alarming rate. Another concern with fossil fuels is the environmental problems associated with burning them in power plants—they produce emissions that are causing acid precipitation to fall in some parts of the country.

Advocates of nuclear energy have long used the argument that nuclear-fueled power plants could produce an economical alternative to fossil fuel generated electricity. Opponents of nuclear power



## INTRODUCING CHAPTER 1

### DISCOVERY LEARNING

▶ *Activity Book*

Begin your introduction to this chapter by using the Chapter 1 Discovery Activity from the *Activity Book*. Using this activity, students will make an electroscope and use it to detect static electricity.

### USING THE TEXTBOOK

Have students observe the photograph on page P10.

• **Where did the electricity for this old laboratory come from?** (Most students will have noticed the lightning bolt hitting the top of the tower.)

Discuss with students the importance of the role of electricity in everyday life. They should be able to come up with a great many applications and can be led to the conclusion that many of the impor-

# Electric Charges and Currents

## Guide for Reading

*After you read the following sections, you will be able to*

**1-1 Electric Charge**

- Relate electric charge to atomic structure.
- Describe the forces that exist between charged particles.

**1-2 Static Electricity**

- Describe the effects of static electricity.

**1-3 The Flow of Electricity**

- Describe the nature of current electricity.

**1-4 Electric Circuits**

- Identify the parts of an electric circuit.
- Compare a series and a parallel circuit.

**1-5 Electric Power**

- Explain how electric power is calculated and purchased.

Creepy characters . . . dark nights . . . thunder and lightning crashing in the background . . . castles with trap doors and secret laboratories. Do these descriptions sound familiar to you? Perhaps you have seen them in monster movies such as *Frankenstein* and *The Bride of Frankenstein.* These exciting movies often express people's hidden hopes and fears about a world in which scientific knowledge can be used for either good or evil. Usually, electricity is used at some point in the movie to mysteriously create life or to destroy it.

For hundreds of years, many people were frightened by electricity and believed it to have mysterious powers. Today a great deal is known about electricity. And although it is not mysterious, electricity plays a powerful role in your world. Electricity is involved in all interactions of everyday matter—from the motion of a car to the movement of a muscle to the growth of a tree. Electricity makes life easier and more comfortable. In this chapter you will discover what electricity is, how it is produced and used, and why it is so important.

### Journal *Activity*

***You and Your World*** Did you switch on a light, shut off an alarm clock, listen to the radio, or turn on a hair dryer today? In your journal, describe the importance of electricity in your daily life. Include any questions you may have about electricity.

*Dr. Frankenstein at work in his laboratory.*



ant activities that make up their days rely directly or indirectly on electricity—everything from waking up on time because of the ringing of an electric alarm clock to preserving and cooking food to transportation to extending the activities of the daytime by means of electric lights.

Have students read the chapter introduction. Discuss the use of light and/or electricity in horror or science-fiction movies. Students may mention movies such as *Star Wars, Return of the Jedi, Back to the Future,* and so on.

- **Why do movie makers use lightning, light, and electricity as a means to show the power and strength of evil and good?** (Responses might include that light, lightning, and electricity can, because of their properties, depict powerful forces in a startling and dramatic way.)

have always raised the threat of safety to both the public and the environment in opposing the licensing of these plants.

In a recent California election, a 15-year-old nuclear power plant was closed down by the community. The campaign against the plant centered on economics, not on the emotional issues of personal and environmental safety. The plant produced only 40 percent of the electricity that had been expected, and the electricity that was produced cost twice as much as electricity purchased from conventional power plants. Residents in the area felt that the economic reality of nuclear power did not justify the potential risk associated with the plant. What is the future of nuclear power in the United States?

**Cooperative learning:** Using preassigned lab groups or randomly selected teams, have groups complete one of the following assignments:

- Have groups prepare a list of interview questions that would answer the "five W's" (What, When, Why, Where, and Who) about the electricity that is used in their community. If possible, invite a representative from the power company to class for the purpose of answering the interview questions. If this option is not available (and to prevent too many phone calls to the utility company), randomly assign one group to conduct the interview by phone.
- Have students react to the following statement: Nuclear-fueled power plants should continue to be built and allowed to operate. Reactions can take the form of posters, public service announcements for TV or radio, letters to the editor, billboards, bumper stickers, T-shirts, or any format that you approve, but they must in some way explain the reason(s) for the group's reaction.

See Cooperative Learning in the *Teacher's Desk Reference.*

### JOURNAL ACTIVITY

You may want to use the Journal Activity as the basis of a class discussion. You may wish to suggest that students also include devices that are powered with gas or light energy. Which source of energy seems to be used most frequently, electric, gas, or solar? Students should be instructed to keep their Journal Activity in their portfolio.

# 1-1 Electric Charge

## MULTICULTURAL OPPORTUNITY 1-1

Depending upon the background of your students, they may have widely differing experiences with electricity. Some students fear that D-cell batteries will cause shocks whereas other students might understand how the wiring in their own homes operates. Begin this section by discussing electricity with your students and eliciting some of these misconceptions.

## ESL STRATEGY 1-1

When discussing that charge is the basic property of both protons and electrons, point out that the word *charge* has many different meanings other than its scientific usage. Have students find two other meanings in their dictionaries and then write three sentences to demonstrate their understanding of the three meanings of charge.

Have students form two sentences stating the rule of electric charges by unscrambling the following words. The sentences should include proper capitalization and punctuation.

other—charges—unlike—attract—each—

charges—like—each—repel—other

## TEACHING STRATEGY 1-1

### FOCUS/MOTIVATION

Ask students to imagine a world in which there were no electrical devices and to think of how their ancestors were able to carry out everyday functions without the benefit of electricity.

### CONTENT DEVELOPMENT

After students have been given a feeling for the many applications and aspects of electricity, lead them to wonder about the basis of this phenomenon. Introduce—or reintroduce—the concept of the atom to them. Discuss the most important subatomic particles and the concept of charge.

**Guide for Reading**

*Focus on these questions as you read.*

- *What is the source of electric charge?*
- *How do electric charges behave?*

# 1–1 Electric Charge

Have you ever rubbed a balloon on your clothing to make it stick to you or to a wall? Or have you ever pulled your favorite shirt out of the clothes dryer only to find socks sticking to it? How can objects be made to stick to one another without glue or tape? Believe it or not, the answer has to do with electricity. And the origin of electricity is in the particles that make up matter.

## Atoms and Electricity

All matter is made of **atoms.** An atom is the smallest particle of an element that has all the properties of that element. An element contains only one kind of atom. For example, the element lead is made of only lead atoms. The element gold is made of only gold atoms.

Atoms themselves are made of even smaller particles. Three of the most important particles are **protons, neutrons,** and **electrons.** Protons and neutrons are found in the nucleus, or center, of an atom. Electrons are found in an area outside the nucleus often described as an electron cloud. **Both protons and electrons have a basic property called charge.** Unlike many other physical properties of matter, **charge** is not something you can see, weigh, or define. However, you can observe the effects of charge—more specifically, how charge affects the behavior of particles.

The magnitude, or size, of the charge on the proton is the same as the magnitude of the charge on the electron. The kind of charge, however, is not the same for both particles. Protons have a positive charge, which is indicated by a plus symbol (+). Electrons have a negative charge, which is indicated by a minus symbol (−). Neutrons are neutral, which means that they have no electric charge. The terms positive and negative, which have no real physical

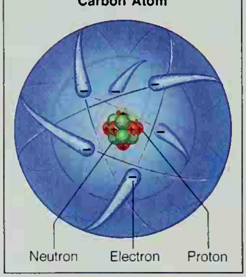



**Figure 1–1** *The diagram of the carbon atom shows the arrangement of subatomic particles known as protons, neutrons, and electrons. Carbon is found in all living organisms, including this hungry hippo.*



### Integration

Use the discussion of subatomic particles to integrate concepts of atoms into your lesson.

### GUIDED PRACTICE

**Skills Development**

***Skill: Interpreting illustrations***

Have students examine Figure 1–1, which shows the subatomic particles in a carbon atom.

- **Electrons are particles that have a negative charge. Where are the electrons shown in the diagram?** (Near the outer edge of the circle.)
- **Where are the protons and neutrons?** (Grouped together in the center, or nucleus, of the atom.)
- **What is the difference between a proton and a neutron?** (A proton has a positive charge. A neutron is neutral—it has no charge at all.)

ignificance, were originally decided upon by Benjamin Franklin when he first discovered charge. They have been used ever since.

## Charge and Force

The difference between the two charges has to do with how they behave and the **forces** they exert. A force is a pull or push on an object. You are already familiar with various types of forces. Your foot exerts a force (a push) on a ball when you kick it. An ocean wave exerts a force (a push) on you when it knocks you over. The Earth exerts a force (a pull) on the moon to keep it in its orbit. Charged particles exert similar pushes and pulls.

When charged particles come near one another, they give rise to two different forces. A force that pulls objects together is a force of attraction. **A force of attraction exists between oppositely charged particles.** So negatively charged electrons are attracted to positively charged protons. This force of attraction holds the electrons in the electron cloud surrounding the nucleus.

A force that pushes objects apart is a force of repulsion. **A force of repulsion exists between particles of the same charge.** Negatively charged electrons repel one another, just as positively charged protons do. Electric charges behave according to this simple rule: *Like charges repel each other; unlike charges attract each other.*

### FIND OUT BY DOING

*Electric Forces*

**1.** Take a hard rubber (not plastic) comb and rub it with a woolen cloth.

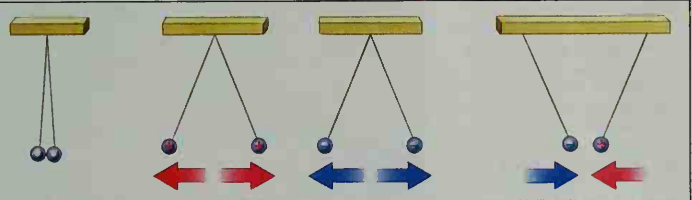
**2.** Bring the comb near a small piece of cork that is hanging from a support by a thread.

**3.** Allow the comb to touch the cork, and then take the comb away. Bring the comb toward the cork again.

**4.** Repeat steps 1 to 3 using a glass rod rubbed with silk. Then bring the rubber comb rubbed with wool near the cork.

■ Record and explain your observations.

**Figure 1–2** *When charged particles come near each other, a force is produced. The force can be either a force of attraction or a force of repulsion. What is the rule of electric charges?* 1






### ANNOTATION KEY

**Answers**

1 Unlike charges attract each other. Like charges repel each other. (Making generalizations)

**Integration**

1 Physical Science: Atoms. See *Matter: Building Block of the Universe*, Chapter 4.

2 Physical Science: Force. See *Motion, Forces, and Energy*, Chapter 2.

### FIND OUT BY DOING

ELECTRIC FORCES

**Discovery Learning**

***Skills: Applying concepts, making observations, making comparisons***

***Materials: hard rubber comb, woolen cloth, cork, thread, glass rod, silk***

This activity will help to introduce the concept that electric forces build up when electrons are forced to move from one object to another. Students should be able to relate their observations to the concepts that like charges repel each other and opposite charges attract each other.

### CONTENT DEVELOPMENT

You can help to make clear the concept of attractive and repulsive forces by means not only of charged objects (for example, like- and unlike-charged lightweight objects suspended near one another from strings), but also of magnets. Do not become too involved in the specifics of the nature or magnitudes of forces; simply deal qualitatively with attractions and repulsions. Direct students' attention to Figure 1–2, which clearly shows the three different possibilities for charge interaction.

**• • • • Integration • • • •**

Use the discussion of the forces exerted by charged particles to integrate concepts of force into your lesson.

### ENRICHMENT

Ask students to design an experiment to test the way in which distance between charged objects affects forces of attraction and repulsion. They may come up with any of a wide variety of ways to measure how great a push or pull is exerted when the objects are at different distances apart.

### REINFORCEMENT/RETEACHING

▶ *Activity Book*

Students who have difficulty understanding the concepts of attraction and repulsion should be provided with the Chapter 1 activity called Electric Charge and Force.

## ANNOTATION KEY

**Answers**

Accept all logical answers. Most students will probably have experienced static electricity. (Applying concepts)

**Integration**

1 Physical Science: Ions. See *Chemistry of Matter*, Chapter 1.

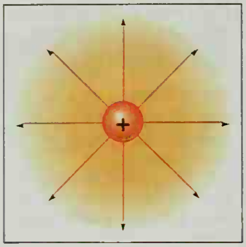
## FIND OUT BY DOING

### BALLOON ELECTRICITY

***Skills: Applying concepts, making observations, making inferences***

***Materials: 3 or 4 medium-sized balloons***

Students will find out that balloons do not stay on the wall on damp or humid days. Remind them that this is because static electricity leaks onto water molecules in the air.



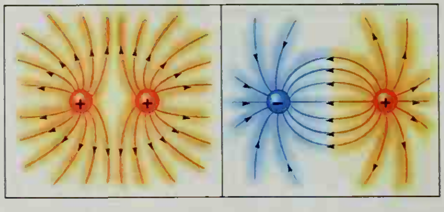


**Figure 1–3** *Lines of force show the nature of the electric field surrounding a charged particle. When two charged particles come near each other, the electric fields of both particles are altered as shown.*

## Electric Field

The attraction and repulsion of charged particles occurs because charged particles have electric fields around them. An **electric field** is an area over which an electric charge exerts a force. When a charged particle moves into the electric field of another charged particle, it is either pushed or pulled depending on the relationship between the two particles.

The electric field is the strongest near the charged particle. As the distance from the charged particle increases, the strength of the electric field decreases. As shown in Figure 1–3, the electric field can be visualized by drawing lines extending outward from a charged particle.

### 1–1 Section Review

1. Describe the charged particles in an atom.
2. What is a force? Give some examples.
3. What is the rule of electric charges?
4. What is an electric field?

**Critical Thinking—*Drawing Diagrams***

5. A positively charged particle is placed 1 centimeter from positively charged particle X. Describe the forces experienced by each particle. Compare these forces with the forces that would exist if a negatively charged particle were placed 10 centimeters from particle X. Draw the electric field surrounding each particle.



## 1–1 (continued)

### INDEPENDENT PRACTICE

**Section Review 1–1**

1. Protons are positively charged and are found in the nucleus of the atom. Electrons are negatively charged and travel in orbits around the nucleus.
2. A force is a push or pull on an object. Examples may include magnetic, gravitational, and nuclear forces as well as electric forces.
3. Like charges repel each other; unlike charges attract each other.
4. The region surrounding a charged particle in which an electric force on other charged particles is noticeable.
5. The positively charged particle experiences a force of repulsion, whereas the negatively charged particle experiences a force of attraction. The force of repulsion is stronger because the positively charged particle is closer to particle X than the negatively charged particle is.

Student diagrams should resemble those shown in Figure 1-3. Encourage student creativity in showing the difference between the strengths of the two fields. Students might use a greater number of arrows or heavier lines for the stronger field.

### REINFORCEMENT/RETEACHING

Review students' responses to the Section Review questions. Reteach any material that is still unclear, based on students' responses.

### CLOSURE

▶ *Review and Reinforcement Guide*

Have students complete Section 1–1 in the *Review and Reinforcement Guide*.

## TEACHING STRATEGY 1–2

### FOCUS/MOTIVATION

Rub several balloons with a piece of fur or cloth, preferably wool. Stick the balloons to a classroom wall.

## 1–2 Static Electricity

From your experience, you know that when you it on a chair, pick up a pen, or put on your jacket, ou are neither attracted nor repelled by these bjects. Although the protons and electrons in the toms of these objects have electric charges, the bjects themselves are neutral. Why?

An atom has an equal number of protons and lectrons. So the total positive charge is equal to the otal negative charge. The charges cancel out. So ven though an atom contains charged particles, it is lectrically neutral. It has no overall charge.

How then do objects such as balloons and clothng develop an electric charge if these objects are nade of neutral atoms? The answer lies in the fact hat electrons, unlike protons, are free to move. In ertain materials, some of the electrons are only oosely held in their atoms. Thus these electrons can asily be separated from their atoms. If an atom oses an electron, it becomes positively charged ecause it is left with more positive charges (protons) han negative charges (electrons). If an atom gains n electron, it becomes negatively charged. Why? An tom that gains or loses electrons is called an ion.

**igure 1–4** *Is it magic that makes these pieces of paper rise o to the comb? No, just static electricity. Have you ever xperienced static electricity?* 1

**Guide for Reading**

*Focus on these questions as you read.*

- *How do neutral objects acquire charge?*
- *What is static electricity?*

### FIND OUT BY DOING

*Balloon Electricity*

**1.** Blow up three or four medium-sized balloons.

**2.** Rub each balloon vigorously on a piece of cloth. Wool works especially well.

**3.** "Stick" each balloon on the wall. Record the day, time, and weather conditions.

**4.** Every few hours, check the position of the balloons.

**5.** Repeat your experiment on a day when the weather conditions are different—for example, on a dry day versus on a humid or rainy day.

How long did the balloons stay attached to the wall? Why did they eventually fall off the wall?

■ Does weather have any effect? Explain.

P ■ 15

**What causes the balloons to stick?** They have gained electrons from the loth, and now they repel electrons in the vall, leaving that area of the wall nearest hem positively charged. The opposite harges attract one another.)

**Why is this kind of electricity called tatic electricity?** (The electric charges ave built up but do not flow. Static neans "unchanging.")

**What do you predict will happen if harged balloons are brought close to- ether? Why?** (They will repel one another because they have the same charge, and like charges repel.)

Push several well-charged balloons close together to demonstrate what occurs. Bring out that the reasoning, hypothesis formation, and experimentation that are involved illustrate scientific method.

**• • • • Integration • • • •**

Use the discussion of the charges gained and lost by electrons to integrate concepts of ions into your lesson.

# *1–2 Static Electricity*

### MULTICULTURAL OPPORTUNITY 1–2

The Eskimo cultures are exposed to a fascinating example of electricity—the aurora borealis, or northern lights. Have your students investigate the factors necessary for the northern lights to appear.

### ESL STRATEGY 1–2

Write the following sentences on the chalkboard and ask for volunteers to complete them, reading them aloud.

**1.** Neutral objects get electrical charges if they ______ or ______ an electron.
**2.** ______tion occurs when electrons flow through one object to another.
**3.** ______tion occurs when a neutral object comes close to a charged object.
**4.** ______tion occurs when two objects are rubbed together.
(Answers: 1. gain, lose; 2. Conduc; 3. Induc; 4. Fric.)

Have students play a game of "Jeopardy" using electricity as the category. Students take turns giving the terms for each of the following definitions. Answers are given in parentheses.

- Static electricity is lost as electric charges move off an object. (Electric discharge.)
- A dramatic example of static electricity occurring when charges move off an object. (Lightning.)
- Electrons move from one object to another, cause buildup of electric charges, and then remain at rest. (Static electricity.)
- Principle by which lightning rods work. (Grounding.)
- Instrument used to detect electric charge. (Electroscope.)

FIND OUT BY DOING

SPARK, CRACKLE, MOVE

**Discovery Learning**

***Skills: Applying concepts, making observations, making inferences***

***Materials: comb, running water from faucet, wool carpet, metal pen, doorknob***

This activity will help students observe the effects and buildup of static electricity. These activities work best on dry, cool days.

Have students relate their observations to the discussion in the textbook. In each case rubbing has caused an object to lose some of its electrons and become positively charged.

## FIND OUT BY DOING

*Spark, Crackle, Move*

**1.** Comb your hair several times in the same direction. Then bring the comb near your hair, but do not touch it.

**2.** Repeat step 1 but now bring the comb near a weak stream of water from a faucet.

**3.** In a darkened room, walk across a wool carpet and then touch a doorknob with a metal pen or rod.

■ Provide an explanation for each observation.

Just as an atom can become a negatively or positively charged ion, so can an entire object acquire a charge. **A neutral object acquires an electric charge when it either gains or loses electrons.** Remember, only electrons move. Also remember that charge is neither being created nor destroyed. Charge is only being transferred from one object to another. This is known as the Law of Conservation of Charge.

### Methods of Charging

When you rub a balloon against a piece of cloth, the cloth loses some electrons and the balloon gains these electrons. The balloon is no longer a neutral object. It is a negatively charged object because it has more electrons than protons. As the negatively charged balloon approaches a wall, it repels the electrons in the wall. The electrons in the area of the wall nearest the balloon move away, leaving that area of the wall positively charged. See Figure 1–6. Using the rule of charges, can you explain why the balloon now sticks to the wall? 1

Rubbing two objects together is one method by which an object can become charged. This method is known as the **friction** method. In the previous example, the balloon acquired a charge by the friction method. That is, it was rubbed against cloth.

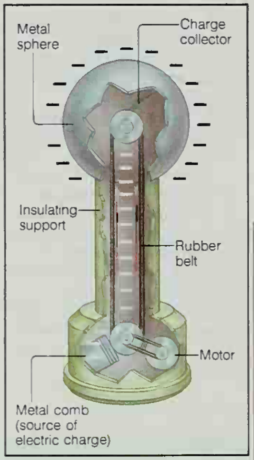



**Figure 1–5** *A Van de Graaff generator produces static electricity by friction. Electrons ride up a rubber belt to the top of the generator, where they are picked off and transferred to the metal sphere. The charge that has built up on the generator at the Ontario Science Center is large enough to make this girl's hair stand on end.*



## 1–2 (continued)

### CONTENT DEVELOPMENT

Direct students' attention again to Figure 1–3, which depicts lines of force between pairs of charges. Tie this field concept to the discussion of static electricity, pointing out the static nature of the field in this case. Later, you can contrast this with the changing electric field characteristic of flowing electricity. This will also help to prepare students for the concept of magnetic fields (treated in the following chapter), which result from changing electric fields.

### FOCUS/MOTIVATION

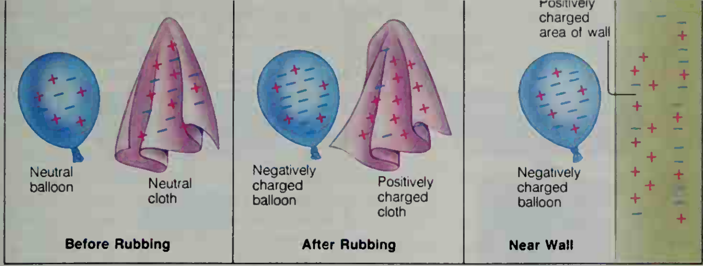
Ask students to experiment on a number of different materials (such as various plastics and fabrics) in order to determine which substances tend to be charged easily when rubbed. Students should work with different combinations of substances. They can also attempt to determine whether positive or negative charge develops in each by observing whether attraction or repulsion results when a negatively charged balloon, for example, is brought near the charged object.

### CONTENT DEVELOPMENT

Explain that charging objects through rubbing is called the friction method of creating electric charge. For example, if a glass rod is rubbed with silk, electrons are transferred from the rod to the silk.

• **Which object has become negatively charged? Positively charged?** (The silk has become negatively charged. The rod has lost electrons and become positively charged.)

• **Which object would be attracted to the balloon described in the textbook? Why?** (The balloon is negatively charged, so it would attract the rod. The balloon and the silk would repel each other.)

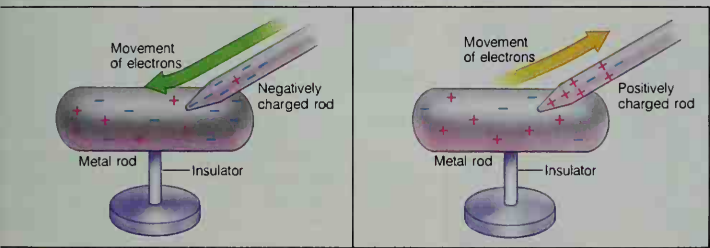



Another method of charging is **conduction.** In conduction, which involves the direct contact of objects, electrons flow through one object to another object. Certain materials permit electric charges to flow freely. Such materials are called **conductors.** Most metals are good conductors of electricity. This is because some electrons in the atoms are free to move throughout the metal. Silver, copper, aluminum, and mercury are among the best conductors. The Earth is also a good conductor.

Materials that do not allow electric charges to flow freely are called **insulators.** Insulators do not conduct electric charges well because the electrons in the atoms of insulators are tightly bound and cannot move throughout the material. Good insulators include rubber, glass, wood, plastic, and air. The rubber tubing around an electric wire and the plastic handle on an electric power tool are examples of insulators.

**Figure 1–6** *Rubbing separates charges, giving the cloth a positive charge and the balloon a negative charge. When the negatively charged balloon is brought near the wall, it repels electrons in the wall. The nearby portion of the wall becomes positively charged. What happens next?* 2

**Figure 1–7** *A metal rod can be charged negatively (left) or positively (right) by conduction.*






## ANNOTATION KEY

### Answers

1 There is a force of attraction between the negatively charged balloon and part of the wall that is positively charged. (Relating cause and effect)

2 The force of attraction between the negatively charged balloon and the positively charged wall will make the balloon "stick" to the wall. (Applying concepts)

### Integration

1 Physical Science: Friction. See *Motion, Forces, and Energy,* Chapter 2.

2 Physical Science: Metals. See *Matter: Building Block of the Universe,* Chapter 5.

#### • • • • Integration • • • •

Use the discussion of the charge on the balloon to integrate concepts of friction into your lesson.

#### CONTENT DEVELOPMENT

Friction is one method of creating electrical charge. Explain that two other methods are conduction and induction. The methods differ in that conduction involves objects coming into direct contact with each other. In induction, the objects only need come close to each other. In conduction, electrons flow from one object to another. In induction, no flow takes place.

Explain that a substance is classified as a conductor or an insulator depending on how tightly the atoms of the substance hold their electrons.

• **What are some materials that are good conductors of electricity?** (Possible examples include various metals.)

• **What are some materials that are good insulators?** (Possible examples include rubber, glass, wood, and plastic.)

Point out that materials that are poor conductors of electricity are generally also poor conductors of heat.

#### • • • • Integration • • • •

Use the discussion of conductors and insulators to integrate concepts of metals into your lesson.

#### GUIDED PRACTICE

▶ *Laboratory Manual*

**Skills Development**

***Skills: Applying concepts, making observations, making comparisons, making inferences***

At this point you may want to have students complete the Chapter 1 Laboratory Investigation in the *Laboratory Manual* called Conductors and Insulators. In the investigation students will test common materials to determine whether they are conductors or insulators.

## HISTORICAL NOTE

### THALES

One of the first people to produce written observations concerning static electricity and magnetism was the Greek philosopher and mathematician Thales (640–546 BC). Thales experimented with amber and found that it would attract objects such as feathers, bits of dried grass, and straw. He noticed that although the amber would attract light objects, it would not attract metal.

## BACKGROUND INFORMATION

### WATER AS A CONDUCTOR

Chemically pure water is actually a rather poor conductor of electricity. Any ordinary, nondistilled water, however, contains in every milliliter large numbers of ions, or charged particles, that do conduct electricity. Thus ordinary water, which is actually a solution of salts, is a relatively efficient conductor. Even distilled water can quickly become a good conductor if any part of the body or clothing comes in contact with it and ions become dissolved in it.

## INTEGRATION

### MATHEMATICS

The magnitude of the force in an electric field is proportional to the product of the charges of the two objects, divided by the square of the distance separating the centers of the objects. This inverse-square relationship accounts for the fact that the magnitude of electric forces decreases rapidly as distance increases.

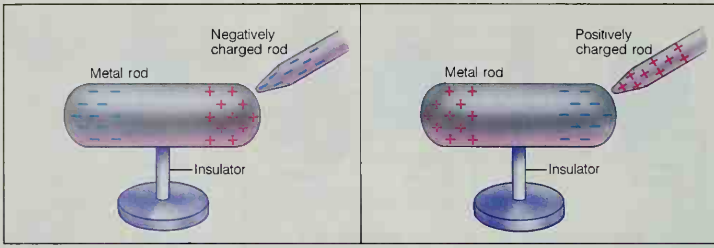
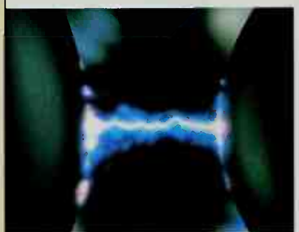



**Figure 1-8** *A charged rod brought near a conductor induces an electric charge in the conductor. How is this different from conduction?* 1

The third method of charging is by **induction.** Induction involves a rearrangement of electric charges. For induction to occur, a neutral object need only come close to a charged object. No contact is necessary. For example, a negatively charged rubber rod can pick up tiny pieces of paper by induction. The electric charges in the paper are rearranged by the approach of the negatively charged rubber rod. The electrons in the area of the paper nearest to the negatively charged rod are repelled, leaving the positive charges near the rod. Because the positive charges are closer to the negative rod, the paper is attracted. Does this description sound familiar? What method of charging made the wall positive in the area nearest the balloon? 2

The transfer of electrons from one object to another without further movement is called **static electricity.** The word static means not moving, or stationary. **Static electricity is the buildup of electric charges on an object.** The electric charges build up because electrons have moved from one object to another. However, once built up, the charges do not flow. They remain at rest.

**Figure 1-9** *The discharge of static electricity from one metal object to another can be seen as a spark.*



### Electric Discharge—Lightning

Electrons that move from one object to another and cause the buildup of charges at rest, or static electricity, eventually leave the object. Sometimes they move onto another object. Usually, these extra electrons escape onto water molecules in the air. (This is why static electricity is much more noticeable on dry days. On dry days the air contains fewer water molecules. Objects are more easily charged



## 1–2 (continued)

### FOCUS/MOTIVATION

Hold a hard rubber comb near confetti pieces made from tissue paper. Then rub the comb with a piece of wool cloth and hold it near the confetti again.

• **Why did the pieces of confetti move?** (Because the comb had become charged. Holding the comb near the pieces causes the electric charges in the pieces to become rearranged.)

### CONTENT DEVELOPMENT

Point out that the comb did not actually touch the confetti, so no charged particles moved from the comb to the confetti. Explain that this process is called induction.

• **How is this different from conduction?** (In conduction, the comb would actually touch the confetti, and charged particles would move from the comb to the confetti.)

### REINFORCEMENT/RETEACHING

Students who might have difficulty understanding conduction and induction can be encouraged to construct physical models of their own design to illustrate transfer of electrons.

To illustrate conduction, the electrons can be represented, for example, by colored pushpins that are inserted into a because charges cannot escape into the air.) When the charged object loses its static electricity, it becomes neutral once again. The balloon eventually falls off the wall because it loses its charge and there is no longer a force of attraction between it and the wall.

The loss of static electricity as electric charges move off an object is called **electric discharge.** Sometimes electric discharge is slow and quiet. Sometimes it is very rapid and accompanied by a shock, a spark of light, or a crackle of noise.

One of the most dramatic examples of the discharge of static electricity is lightning. During a storm, particles contained in clouds are moved about by the wind. Charges may become separated, and there are buildups of positive and negative charges

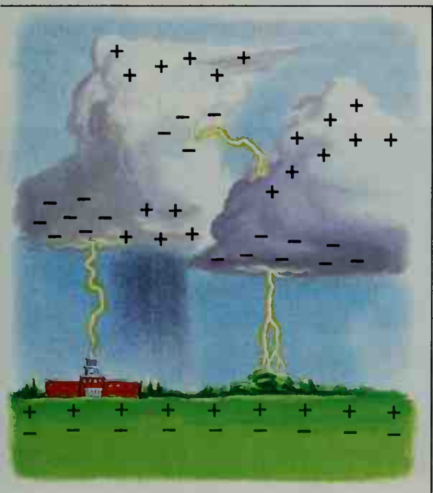


**Figure 1–10** *Lightning is a spectacular discharge of static electricity between two areas of different charge. Lightning can occur between a portion of a cloud and the ground, between different clouds, or between different parts of the same cloud. Benjamin Franklin's famous experiments provided evidence that lightning is a form of static electricity.*

## ANNOTATION KEY

### Answers

1 By conduction, the charge on the metal rod is the same as the charge on the charged rod. By induction, the charge on the metal rod is opposite the charge on the charged rod. (Interpreting diagrams)

2 Induction. (Applying concepts)

### Integration

1 Earth Science: Meteorology. See *Exploring Earth's Weather,* Chapter 1.

## INTEGRATION

### LIFE SCIENCE

Some biochemists and biologists have suggested that the energy from lightning in the primitive atmosphere of the Earth produced complex organic (carbon-containing) molecules from the simple, inorganic ammonia, methane, and water vapor atmosphere present at the time. These molecules made possible the eventual development of life, these scientists conjecture.

square of corkboard and that can be transferred to another corkboard. To illustrate induction, another, "uncharged" board (that is, one that does not contain excess "electron" pins) can be brought near a "negatively charged" one, and some of the pins in the uncharged one can be moved to the end farthest from the charged board.

### FOCUS/MOTIVATION

Ask students to describe what they have observed during lightning storms that have occurred in the past.

• **Where did the lightning originate, and in what direction did it move?** (Although most students believe that all the lightning bolts they have observed moved from the sky downward toward the Earth, many of the bolts probably moved in the other direction, appearances to the contrary.)

### CONTENT DEVELOPMENT

Have students look at the photographs in Figure 1–10.

• **What causes lightning?** (A jumping of electrons to or from clouds that contain particles that have become electrically charged. Some of the energy during the discharge is released as light.)

• **What causes thunder?** (Some of the energy during the discharge is released as heat, which causes a sudden expansion of the air, and therefore generates sound waves.)

**Integration**

Use the discussion of lightning to integrate concepts of meteorology into your lesson.

## BACKGROUND INFORMATION

### SAFETY

Newly manufactured electrical appliances include three-wire power cords that have a safety ground. The ground wire is connected to the case of the appliance. An accidental short circuit will blow a fuse or throw a circuit breaker—a situation far preferable to the user's receiving a dangerous electric shock. Extension cords used with this type of electrical plug must also be of the three-prong type.

Older electrical appliances have a two-wire power cord and should be used with extra caution. In all cases, be sure power cords are in good condition, not cracked or frayed.

## BACKGROUND INFORMATION

### ELECTROSCOPES

The leaves of a charged electroscope become discharged and come together partly because of cosmic radiation from space. Charged particles enter the electroscope at enormous speeds and produce electrical neutrality in the leaves by depositing or carrying away electrons.

in different parts of the cloud. If a negatively charged edge of a cloud passes near the surface of the Earth, objects on the Earth become electrically charged by induction. Negative charges move away from the cloud, and positive charges are left closest to the cloud. Soon electrons jump from the cloud to the Earth. The result of this transfer of electrons is a giant spark called lightning.

Lightning can also occur as electrons jump from cloud to cloud. As electrons jump through the air, they produce intense light and heat. The light is the bolt of lightning you see. The heat causes the air to expand suddenly. The rapid expansion of the air is the thunder you hear.

One of the first people to understand lightning as a form of electricity was Benjamin Franklin. In
1 the mid-1700s, Franklin performed experiments that provided evidence that lightning is a form of static electricity, that electricity moves quickly through certain materials, and that a pointed surface attracts electricity more than a flat surface. Franklin suggested that pointed metal rods be placed above the roofs of buildings as protection from lightning. These rods were the first lightning rods.

Lightning rods work according to a principle called grounding. The term grounding comes from the fact that the Earth (the ground) is extremely large and is a good conductor of electric charge.

**Figure 1–11** *Lightning rods, such as this one on the Canadian National Tower, provide a safe path for lightning directly into the ground. Scientists studying lightning build up large amounts of electric charge in order to create their own lightning.*



## 1–2 (continued)

### CONTENT DEVELOPMENT

Discuss the role of lightning rods in providing protection from lightning. You may wish to have students do library research on some of the various designs for such devices. Students can also do research on whether such devices are used in the school, in their homes, or in nearby public buildings. Other safety aspects related to the subject of lightning—for example, precautions to take if one is caught outdoors during a lightning storm—can also be discussed.

### • • • • Integration • • • •

Use the discussion of Benjamin Franklin's experiments to integrate concepts of social studies into your lesson.

### FOCUS/MOTIVATION

An electroscope can be constructed from a clean, clear bottle. Fit the bottle with a one-hole rubber stopper. Push the end of a heavy, noninsulated copper wire through the stopper (a coat hanger that has been sanded may also be used). Bend the top end of the wire to make a loop and the bottom end of the wire to make a hook. Drape an aluminum strip about 1 centimeter by 10 centimeters over the hook at the bottom of the wire. The two leaves of the aluminum strip will move apart when a charged object is placed near or on the loop at the top of the wire.

Charge a comb by rubbing it three times on a piece of wool. Touch the comb to the loop and have students notice how far apart the leaves of the aluminum strip

The Earth can easily accept or give up electric charges. Objects in electric contact with the Earth are said to be grounded. A discharge of static electricity usually takes the easiest path from one object to another. So lightning rods are attached to the tops of buildings, and a wire connects the lightning rod to the ground. When lightning strikes the rod, which is taller than the building, it travels through the rod and the wire harmlessly into the Earth. Why is it dangerous to carry an umbrella during a lightning storm? 1

Unfortunately, other tall objects, such as trees, can also act as grounders. That is why it is not a good idea to stand near or under a tree during a lightning storm. Why do you think it is dangerous to be on a golf course during a lightning storm? 2

## The Electroscope

An electric charge can be detected by an instrument called an **electroscope.** A typical electroscope consists of a metal rod with a knob at the top and a pair of thin metal leaves at the bottom. The rod is inserted into a one-hole rubber stopper that fits into a flask. The flask contains the lower part of the rod and the metal leaves. See Figure 1–12.

In an uncharged electroscope, the leaves hang straight down. When a negatively charged object

### FIND OUT BY DOING

*Observing Static Electricity*

**1.** Place two books about 10 centimeters apart on a table.

**2.** Cut tiny paper dolls or some other objects out of tissue paper and place them on the table between the books.

**3.** Place a 20- to 25-centimeter-square piece of glass on the books so that the glass covers the paper dolls.

**4.** Using a piece of silk, rub the glass vigorously. Observe what happens.

■ Using the rule of electric charges and your knowledge of static electricity, explain what you observed.

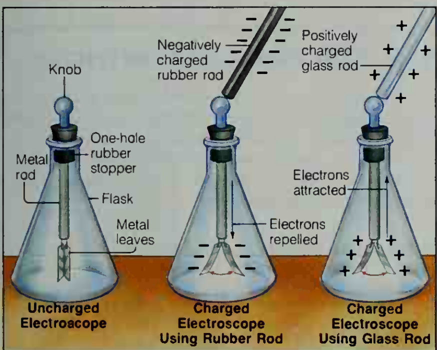



**Figure 1–12** *An electroscope is used to detect electric charges. Why do the leaves in the electroscope move apart when either a negatively charged rubber rod or a positively charged glass rod makes contact?* 3



## ANNOTATION KEY

### Answers

1 The top of the umbrella might attract the lightning. (Applying concepts)

2 A golf course has few, if any, trees or other tall objects. You might be the tallest object in the area and thus attract the lightning. (Making inferences)

3 Because both leaves develop the same charge, and like charges repel each other. (Applying concepts)

### Integration

1 Social Studies

## FIND OUT BY DOING

### OBSERVING STATIC ELECTRICITY

**Discovery Learning**

***Skills: Applying concepts, making observations, making comparisons, relating cause and effect***

***Materials: 2 books, tissue paper, scissors, square piece of glass, piece of silk***

In this activity students cause static electricity to build up on various objects and observe the effects of unlike charges attracting and like charges repelling. Make sure students relate their observations to the textbook discussion.

move. Next, rub the comb six times with the wool.

• **What do you predict will happen if the comb touches the loop at the top of the wire?** (The leaves of the aluminum strip will move farther apart than in the previous demonstration.)

• **What can you conclude from the distance the leaves of the strip move?** (There is more charge on the comb than there was before.)

### CONTENT DEVELOPMENT

Explain the use of the electroscope, directing students' attention to Figure 1–12. If an electroscope is available, demonstrate its ability to be charged by conduction and induction, using charged rubber and glass rods. Ask students to attempt to explain what happens on the basis of their knowledge of electric charge.

### REINFORCEMENT/RETEACHING

▶ *Activity Book*

Students who have difficulty understanding the concepts of conduction and induction should be provided with the Chapter 1 activity called A Giant Electroscope.

# 1-3 The Flow of Electricity

## MULTICULTURAL OPPORTUNITY 1-3

Have your students investigate the life and work of the African-American inventor, Garrett Morgan (1875–1963). Morgan's many contributions include the invention of the first automatic traffic light in 1923. This invention was the forerunner of the modern red-yellow-green traffic signals that we see today.

## ESL STRATEGY 1-3

Write these three terms on the chalkboard: *thermocouples, batteries, photocells.* Ask students to give the singular form of each term. (Thermocouple, battery, photocell.) Then have them use the terms and the following three descriptions to write complete sentences.

1. change light into electrical energy
2. produce electrical energy from heat energy
3. produce electricity by converting chemical energy into electrical energy

(Answers: 1. photocells; 2. thermocouples; 3. batteries.)

Have students circle the word that does not belong in the group and give reasons for their choice.

• amperes, bolts, ohms, volts

(Answer: Bolts. The others are units of measurement related to electricity.)

touches the metal knob, electric charges travel down the rod and into the leaves. The leaves spread apart, indicating the presence of an electric charge. Since the charge on both leaves is the same, the leaves repel each other and spread apart.

If a positively charged object touches the knob of the electroscope, free electrons in the leaves and metal rod are attracted by the positive object. The loss of electrons causes the leaves to become positively charged. Again, they repel each other and spread apart.

### 1–2 Section Review

1. What are three ways an object can acquire an electric charge?
2. What is static electricity?
3. What is electric discharge? Give an example.
4. If the body of a kangaroo contains millions of charged particles, why aren't different kangaroos electrically attracted to or repelled by one another?

**Critical Thinking—*Making Inferences***

5. What would happen if a lightning rod were made of an insulating material rather than of a conducting material?

**Guide for Reading**

*Focus on these questions as you read.*

▶ *How can a flow of charges be produced?*

▶ *What is the relationship among electric current, voltage, and resistance?*

## 1–3 The Flow of Electricity

The electricity that you use when you plug an electrical appliance into a wall outlet is certainly not static electricity. If it were, the appliance would not run for long. Useful electricity involves the continuing motion of electric charges. Electric charges can be made to continue flowing.

### Producing a Flow of Electrons

1 **A continuing flow of electric charges is produced by a device that changes other forms of energy into electrical energy.** Energy is defined as the ability to do work. You use energy when

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## 1-2 (continued)

### INDEPENDENT PRACTICE

**Section Review 1-2**

1. Friction, conduction, and induction.
2. The buildup of electric charges on an object.
3. The loss of static electricity as electric charges move off an object. One example is lightning.
4. Each atom in the kangaroo has an equal number of protons and electrons. So the charges cancel out one another, and the kangaroo is electrically neutral.
5. The lightning would not be able to travel down the rod, so it would find another pathway—probably through the building that the lightning rod is trying to protect. Thus, a lightning rod made from an insulator would be useless.

### REINFORCEMENT/RETEACHING

Review students' responses to the Section Review questions. Reteach any material that is still unclear, based on students' responses.

### CLOSURE

▶ *Review and Reinforcement Guide*

Have students complete Section 1–2 in the *Review and Reinforcement Guide.*

## TEACHING STRATEGY 1-3

### FOCUS/MOTIVATION

Have students arrange marbles in a row. Have them add another marble to one end of the row, pushing so that the new marble takes the place of the one ahead of it. They should see that the marble all along the row move and that the marble at the far end has been pushed to a new place.

you throw a ball, lift a suitcase, or pedal a bicycle. Energy is involved when a deer runs, a bomb explodes, snow falls—or when electricity flows through a wire. Although there are different types of energy, each type can be converted into any one of the others. A device that converts other forms of energy into electrical energy is known as a source of electricity. Batteries and electric generators are the main sources of electricity. But thermocouples and photocells are other important sources. Electric generators will be discussed in Chapter 3.

**BATTERIES** A **battery** is a device that produces electricity by converting chemical energy into electrical energy. A battery is made of several smaller units called electric cells, or electrochemical cells. Each cell consists of two different materials called electrodes as well as an electrolyte. The electrolyte is a mixture of chemicals that produces a chemical reaction. The chemical reaction releases electric charges.

Electric cells can be either dry cells or wet cells, depending on the type of electrolyte used. In a wet cell, such as a car battery, the electrolyte is a liquid. In a dry cell, such as the battery in a flashlight, the electrolyte is a pastelike mixture.

Figure 1–14 will help you to understand how a simple electrochemical cell works. In this cell, one of the electrodes is made of carbon and the other is made of zinc. The part of the electrode that sticks up is called the terminal. The electrolyte is sulfuric acid. The acid attacks the zinc and dissolves it.

**Figure 1–13** *Imagine plugging a car into the nearest outlet rather than going to the gas station! Researchers have been attempting to design efficient cars that use a rechargeable battery as a source of power.*

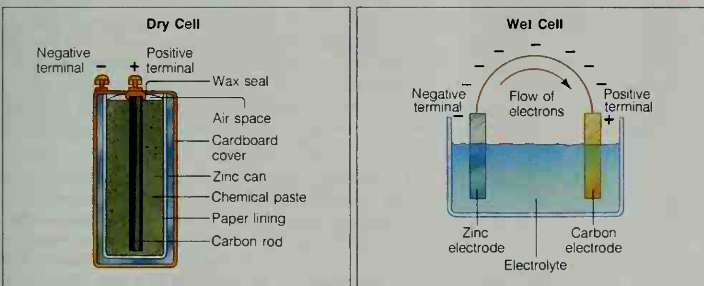



**Figure 1–14** *Electrochemical cells, which include dry cells and wet cells, convert chemical energy into electric energy. What is a series of dry cells called? What is an example of a wet cell?* ❶



## ANNOTATION KEY

### Answers

❶ A battery. (Applying definitions)

### Integration

❶ Physical Science: Work. See *Motion, Forces, and Energy*, Chapter 4.

❷ Physical Science: Electrolytes. See *Chemistry of Matter*, Chapter 3.

## HISTORICAL NOTE

### GALVANI AND VOLTA

Some of the best-known early experiments with electricity were conducted by the Italian biologist Luigi Galvani (1737–1798). While dissecting a frog, Galvani observed muscular reactions in the frog's leg when the leg was placed in contact with two dissimilar metals. Frog nerves turned out to be extremely sensitive detectors of electrical charges.

Inspired by published reports of Galvani's experiments, Alessandro Volta (1745–1827) was eventually able to demonstrate the phenomenon of current electricity. The device Volta used became known as Volta's "pile," and was the earliest electric battery.

## CONTENT DEVELOPMENT

Explain that electrons move in a way similar to that of marbles in a long tube. When the tube is full of marbles, one needs to push only one marble into one end of the tube, and a marble will immediately emerge from the far end of the tube.

### • • • • Integration • • • •

Use the definition of energy to integrate concepts of work into your lesson.

## FOCUS/MOTIVATION

You may wish to ask a student who has knowledge of automobiles to research and to present to the class information on automobile batteries, which are made up of a series of wet cells. The student may also explain the role of the battery and of the automobile electrical system as a whole.

Alternatively, you may wish to arrange to have an industrial/automotive-arts teacher or a local auto mechanic address the class or even demonstrate the workings of an automobile battery and of an engine thermocouple.

## CONTENT DEVELOPMENT

Direct students' attention to Figure 1–14, which shows a dry and a wet cell. Go over the features of these sources of current, and, if possible, demonstrate each in class. Ask students to try to analyze the processes occurring in each.

Explain that when the chemical action takes place in a cell, an electrical force called electromotive force, or electrical potential (voltage), causes a current of electricity to flow. Have students observe the positive and negative terminals in the figure. Point out that the electron flow is from the negative to the positive.

### • • • • Integration • • • •

Use the discussion of dry and wet cells to integrate electrolytes into your lesson.

## BACKGROUND INFORMATION

### CURRENT

Current, or the rate of flow of electric charge, is measured in amperes. The ampere unit itself, as a rate unit, is actually equal to a basic unit of electric charge, the coulomb, divided by a unit of time, the second. One coulomb is the amount of charge carried by $6.25 \times 10^{18}$ electrons. A current of 1 ampere is equal to a flow rate of 1 coulomb per second.

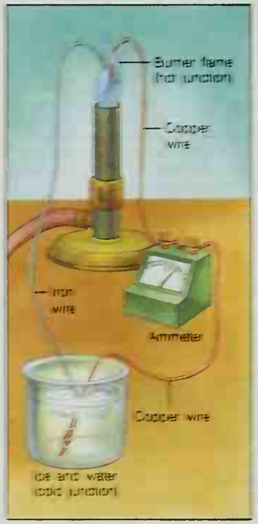
## BACKGROUND INFORMATION

### THE PHOTOELECTRIC EFFECT

The photoelectric effect is the ejection of electrons from certain metals when light falls upon them. This effect is used in electric eyes, light meters, in the sound tracks of motion pictures, and in the photoelectric cells described in the text.

The theory describing the photoelectric effect was first published by Albert Einstein. In his theory, light consists of photons—bundles of electromagnetic energy that do not have mass. Einstein's experiments and research concerning the photoelectric effect led him to the quantum theory of light.

**Figure 1–15** *The temperature difference between the hot junction and the cold junction in a thermocouple generates electricity. What is the energy conversion involved in the operation of a thermocouple?* 1






In this process, electrons are left behind on the zinc electrode. Thus the zinc electrode becomes negatively charged. At the same time, a series of chemical reactions causes electrons to be pulled off the carbon electrode. The carbon electrode becomes positively charged. Because there are opposite charges on the electrodes, charge will flow between the terminals if a wire connects them. The difference in charge is called a **potential difference.** A potential difference is like a hill. If a ball is placed at the top of the hill and is allowed to roll down, it will. The steeper the hill, the faster the ball will roll. Similarly, if a potential difference exists between two terminals and a wire connects the terminals, charge will flow. The greater the potential difference, the faster the charge will flow. If the ball is at the bottom of the hill, work will have to be done to roll it up the hill. Work must also be done to move a charge against a potential difference.

THERMOCOUPLES A **thermocouple** is a device that produces electrical energy from heat energy. A thermocouple releases electric charges as a result of temperature differences. In this device the ends of two different metal wires, such as copper and iron, are joined together to form a loop. If one iron-copper junction is heated while the other is cooled, electric charges will flow. The greater the temperature difference between the junctions, the faster the charges will flow. Figure 1–15 shows a thermocouple.

Thermocouples are used as thermometers in cars to show engine temperature. One end of the thermocouple is placed in the engine, while the other end is kept outside the engine. As the engine gets warm, the temperature difference produces a flow of charge. The warmer the engine, the greater the temperature difference—and the greater the flow of charge. The moving charges in turn operate a gauge that shows engine temperature. Thermocouples are also used in ovens and in gas furnaces.

PHOTOCELLS The most direct conversion of energy occurs in a device known as a **photocell.** A photocell takes advantage of the fact that when light with a certain amount of energy shines on a metal surface, electrons are emitted from the surface. These electrons can be gathered in a wire to create a constant flow of electric charge.

### 1–3 (continued)

#### REINFORCEMENT/RETEACHING

Point out that electricity does work only when it flows. One method to obtain the needed flow of electric current is to use an electrochemical cell. Remind students that a dry cell and storage battery consists of chemicals that react with metals. The current that results is a steady flow of electrons. Point out that this steady flow will cease only when all the chemicals are used up or when the circuit is broken. Show students a flashlight that is turned on.

• **How could you break the circuit in this flashlight?** (Most students will know that the circuit can be broken by turning the flashlight off.)

#### CONTENT DEVELOPMENT

Have students examine Figure 1–15 and read the caption. Explain that a thermocouple, like a battery, is a device that produces electrical energy.

• **What is the difference between a thermocouple and a battery?** (A thermocouple uses heat energy. Point out that the prefix *thermo* indicates heat.)

#### • • • • Integration • • • •

Use the discussion of thermocouples to integrate concepts of heat into your lesson.

#### INDEPENDENT PRACTICE

▶ *Activity Book*

Students can investigate other sources of electricity in the Chapter 1 activity called Producing Electricity.

**Figure 1–16** *On November 9, 1965, a major blackout plunged the illuminated skyline of New York City into darkness and left more than 30 million people in the Northeast without electricity.*

## Electric Current

When a wire is connected to the terminals of a source, a complete path called a **circuit** is formed. Charge can flow through a circuit. A flow of charge is called an electric **current.** More precisely, electric current is the rate at which charge passes a given point. The higher the electric current in a wire, the faster the electric charges are passing through.

The symbol for current is the letter I. And the unit in which current is expressed is the ampere (A). The ampere, or amp for short, is the amount of current that flows past a point per second. Scientists use instruments such as ammeters and galvanometers to measure current.

You may wonder how charge can flow through a wire. Recall that conductors are made of elements whose atoms have some loosely held electrons. When a wire is connected to the terminals of a source, the potential difference causes the loose electrons to be pulled away from their atoms and to flow through the material.

You may also wonder how lights and other electrical appliances can go on as soon as you turn the switch even though the power plant may be quite a distance away. The answer is that you do not have to wait for the electrons at the power plant to reach your switch. All the electrons in the circuit flow as soon as the switch is turned. To help understand this concept, imagine that each student in Figure 1–17

### FIND OUT BY READING

*Life on the Prairie*

Not very long ago, people just like you grew up without the electrical devices that make your life easy, comfortable, and entertaining. In *Little House on the Prairie* and its related books, Laura Ingalls Wilder tells delightful stories about growing up in the days before electricity. These stories are especially wonderful because they are not tainted by fictional drama. The author simply describes life as it actually was. 2



### ANNOTATION KEY

Answers

1 Heat energy is converted into electrical energy. (Applying concepts)

Integration

1 Physical Science: Heat. See *Heat Energy*, Chapter 2.

2 Language Arts

### FIND OUT BY READING

LIFE ON THE PRAIRIE

***Skill: Reading comprehension***

This activity provides students with an opportunity to imagine what life would be like without the electricity and the many electrical appliances that they probably take for granted.

After students have read Wilder's book, have them prepare short essays describing how they might use modern inventions to solve problems faced by the characters in the book.

Interested students may also enjoy reading *Always the Young Strangers* by Carl Sandburg, in which Sandburg depicts small town life in the late 1800s.

**Integration:** Use the Find Out by Reading feature to integrate language arts into your science lesson.

### CONTENT DEVELOPMENT

Emphasize that the flow of electrons or electricity through a wire is called an electric current. Point out that current is usually measured in amperes. Most houses are wired to carry up to 200 amperes of electric current. Emphasize that current is the number of electrons that pass a given point in a unit of time.

• **If ten electrons flow past a point during one second, what is the current?** (Ten electrons per second.)

### ENRICHMENT

Explain that a galvanometer is a measuring device that depends on the magnetic effect produced by an electric current. Students may create galvanometers in the following way.

Attach a small compass to a piece of cardboard, using transparent tape. Cut two slots in the cardboard, one at the north marking of the compass and one at the south marking. Then wind about 50 turns of insulated copper wire through the slots and around the compass. Leave about 30 centimeters of wire free at each end.

Remove the insulation from the free ends of the wire and attach the ends to the terminals of an electric cell. The needle of the compass will move, showing that current is flowing through the coil of wire. Reversing the free ends of the wire will cause the flow of current to reverse.

## ECOLOGY NOTE

### THERMAL POLLUTION

Generating plants that produce electricity create waste heat as one byproduct of the process. Released into the environment in the form of hot water, this heat can cause environmental problems for organisms living in nearby bodies of water. Excess heat in ecosystems can kill organisms that require narrow temperature ranges or can affect the ability of organisms to reproduce. An increase in temperature can have a negative effect on an entire aquatic community.

Two approaches to the problem of thermal pollution are finding ways to recycle and make use of waste heat and using closed-cycle cooling. In closed-cycle cooling, cooling ponds, cooling canals, or cooling towers are used to safely dispose of heat energy through water evaporation.

## CAREERS

### Electrical Engineer

The people who design and develop electrical and electronic equipment are called **electrical engineers.** Some electrical engineers specialize in a particular area, such as computer systems, integrated circuitry, or communication equipment. For more information, write to the Institute of Electrical Engineers, U.S. Activities Board, 1111 19th Street, NW, Washington, DC 20036.

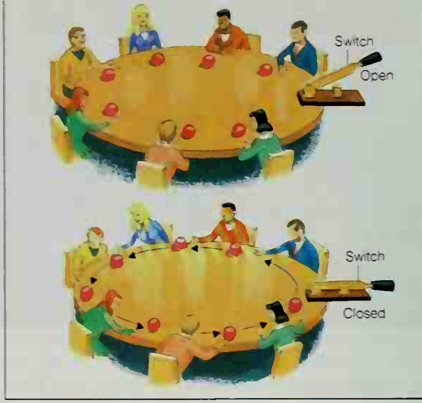



**Figure 1–17** *When the switch in the diagram is closed, the students each pass a ball to the right. Thus a ball reaches the switch almost instantly. Similarly, when you flip on a switch to a light, for example, current flows to the light almost immediately.*

has a red ball. When the switch is turned on, each student passes the ball to the person on the right. So almost as soon as the switch is turned on, a red ball reaches the switch. When the switch is turned off, each person still holds a ball—even though it may not be the original ball. This is basically how electrons shift through a conductor. The electrons shift positions, but no electrons leave the circuit.

### Voltage

You have already learned that a current flows whenever there is a potential difference between the ends of a wire. The size of the potential difference determines the current that will flow through the wire. The greater the potential difference, the faster the charges will flow. The term **voltage** is often used to describe potential difference. The symbol for voltage is the letter V. Voltage is measured in units called volts (V). If you see the marking 12 V, you know that it means twelve volts. An instrument called a voltmeter is used to measure voltage.

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## 1–3 (continued)

### FOCUS/MOTIVATION

Tell students to mentally count the number of times they have turned on the flow of electricity that day.

• **What did you do to turn on the flow of electricity?** (Responses might include turned on a switch, plugged something in, or pushed down a lever.)

### CONTENT DEVELOPMENT

Carefully contrast current and voltage, both as to the nature of these quantities and as to the units used to measure them. Be sure to point out that current, which depends on the number of electrons, is not simply the flow of electrons but also the rate of their flow per unit time.

• **What is measured in amperes?** (Current.)

• **What is measured in volts?** (Voltage.)

• **What is the difference between current and voltage?** (Current is the rate of flow of electrons. Voltage is a measure of energy available to move electrons.)

• **What is the difference between amps and volts?** (Amps are used to measure current. Volts are used to measure voltage.)

### REINFORCEMENT/RETEACHING

Students sometimes receive the faulty impression that voltage is related to the number of electrons, high-voltage conditions being involved only when a great many electrons move. Actually, voltage depends on the energy of each electron and not at all on the number of electrons, which, as students will discover, is related to current.

### CONTENT DEVELOPMENT

Voltage is involved in any situation in which there is a difference in the potential electric energy of electrons in different parts of a system. The voltage acts as a sort of electromotive force that causes electrons to flow from the area of high potential energy toward the area of low potential energy.

### • • • • Integration • • • •

Use the discussion of the potential difference in the human heart to integrate concepts of muscles into your lesson.

Voltage is not limited to the electrical wires that run your appliances. Voltage, or potential difference, is crucial to your survival. A potential difference exists across the surface of your heart. Changes in the potential difference can be observed on a monitor and recorded as an electrocardiogram (EKG). An EKG is a powerful tool used to locate defects in the heart. Potential differences are also responsible for the movements of your muscles.

In the heart a small region called the pacemaker sends out tiny electrical signals as many as sixty times every minute. This is what causes the heart to beat. Perhaps you may already know that if the heart stops beating, doctors sometimes apply an electric current—potential difference—to the patient's chest. Because the heart is controlled by electricity, it can be made to begin beating again by applying this electric current. If the natural pacemaker fails to work, surgeons can implant an electronic pacemaker.

Humans are not the only organisms that use electricity produced in their bodies. Have you ever heard of electric eels? They truly are electric! An electric eel can produce jolts of electricity up to 650 volts to defend itself or to stun prey. Another type of fish, an electric ray, has a specialized organ in its head that can discharge about 200 volts of electricity to stun and capture prey. Although these voltages may not sound like a lot to you, remember that only 120 volts powers just about everything in your home!

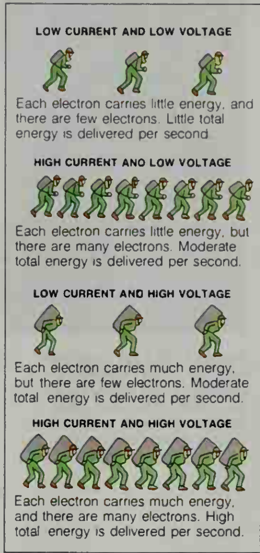



**Figure 1–18** *This diagram shows the relationship between voltage and current. How is current represented? Voltage?* 1

**Figure 1–19** *Although this interesting-looking fish may appear touchable, such a move could prove to be fatal. This is an electric ray, which, like an electric eel, is capable of producing strong jolts of electricity.*



## ANNOTATION KEY

### Answers

1 Voltage is represented by the size of the load carried by each person; current, by the number of people. (Interpreting diagrams)

### Integration

1 Life Science: Muscles. See *Human Biology and Health,* Chapter 2.

2 Life Science: Zoology. See *Parade of Life: Animals,* Chapter 3.

## BACKGROUND INFORMATION

### PEIZOELECTRICITY

Peizoelectricity is the ability of material to generate electricity when pressure is applied or released. In other words, a peizoelectric material will generate an electrical charge when squeezed! Certain asymmetric crystals, such as quartz and tourmaline, exhibit the peizoelectric effect. First discovered in the late 1880s by Pierre Jacques Curie, the peizoelectric effect finds applications in ultrasonic cleaners, ultrasonic submarine detectors, microphones, depth finders, and flameless pilot lights.

## INTEGRATION

### MYTHOLOGY

Early humans often explained mysterious electrical phenomena by creating myths. For example, the Vikings believed that Thor, the god of thunder, created lightning by hurling a magic hammer down to Earth. In the Hudson River Valley, the Dutch settlers often told a humorous folk tale in which thunder was caused by the gods of the nearby hills knocking down pins in a bowling game. This latter tale was the basis for the story of Rip Van Winkle by Washington Irving.

### REINFORCEMENT/RETEACHING

A gravitational analogy may help students understand the concept of voltage. Two points at different distances from a body exerting a gravitational force have different potential energy. The closer point has greater potential energy than the farther point has and will move faster toward the attracting body.

### CONTENT DEVELOPMENT

Have students study Figure 1–18. Point out that the diagrams illustrate four different combinations of current and voltage. The figure shows how the total electrical energy is related to both the amount of current and the amount of voltage.

**• • • • Integration • • • •**

Use the discussion of electric eels and rays to integrate concepts of zoology into your lesson.

## HISTORICAL NOTE

### GEORGE OHM

The German physicist George Ohm (1787–1854) was the first to define the relationships among voltage, current, resistance, and power. Ohm not only showed the relationship among these quantities, but he also specified them in mathematical terms. Many people believe that Ohm's law is the most important single electric formula a student will ever learn.

Ohm is also honored in that his name is used as a unit of measure for resistance. One ohm is the resistance that will allow one ampere to flow with an electromotive force of one volt. An ohm is also defined as the resistance, at 0°C, of a column of mercury 106.3 centimeters in length, of mass 14.4521 grams, and of uniform cross-sectional area.

## BACKGROUND INFORMATION

### OHMMETER

An ohmmeter is an instrument used for measuring resistance in an electrical circuit. An ohmmeter consists of two coils placed at right angles to each other and a small iron needle whose deflection shows a measure of the resistance.

**Figure 1–20** *Light bulbs light because of the phenomenon of resistance. The metal filament in the center of the bulb offers enough resistance to the electric current flowing through it so that heat and light are given off.*

## Resistance

The amount of current that flows through a wire does not depend only on the voltage. It also depends on how the wire resists the flow of electric charge. Opposition to the flow of electric charge is known as **resistance.** The symbol for resistance is the letter R.

Imagine a stream of water flowing down a mountain. Rocks in the stream resist the flow of the water. Or think about running through a crowd of people. The people slow you down by resisting your movement. Electric charges are slowed down by interactions with atoms in a wire. So the resistance of a wire depends on the material of which it is made. If the atoms making up the material are arranged in such a way that it is difficult for electric charge to flow, the resistance of the material will be high. As you might expect, resistance will be less for a wider wire, but more for a longer wire. Higher resistance means greater opposition to the flow of charge. The higher the resistance of a wire, the less current for a given voltage.

The unit of resistance is the ohm (Ω). Different
1 wires have different resistances. Copper wire has less resistance than iron wire does. Copper is a good conductor; iron is a poor conductor. Nonconductors offer such great resistance that almost no current can flow. All electric devices offer some resistance to the flow of current. And although it may not seem so at first, this resistance is often quite useful—indeed, necessary.

You know that light bulbs give off light and heat. Have you ever wondered where the light and heat come from? They are not pouring into the bulb through the wires that lead from the wall. Rather, some of the electric energy passing through the filament of the bulb is converted into light and heat energy. The filament is a very thin piece of metal that resists the flow of electricity within it. The same principle is responsible for toasting your pita bread when you place it in the toaster.

How much resistance a material has depends
2 somewhat on its temperature. The resistance of a metal increases with temperature. At higher temperatures, atoms move around more randomly and thus get in the way of flowing electric charges. At very



## 1–3 (continued)

### FOCUS/MOTIVATION

Allow students do some hands-on work with low-voltage dry cells, ammeters, voltmeters, light bulbs, and wires. Students can be asked to hypothesize on the effects of varying voltages and resistances, and they can then demonstrate experimentally what actually occurs. Encourage students to use scientific method to "discover" Ohm's law (at least qualitatively) on their own, with your supervision, and before they are formally introduced to it in the textbook.

### CONTENT DEVELOPMENT

Have students observe and read the caption to Figure 1–20. Discuss resistance, current, and voltage with some of the following questions.

- **If a different filament with more resistance is used, what should happen to the light bulb?** (It should be brighter.)
- **Why should the bulb be brighter with a filament with greater resistance?** (More of the electrical energy would be converted into light energy.)
- **What should happen to the amount of current through a filament with more resistance?** (The current should be less.)
- **Why should the current be less through a filament with more resistance?** (The resistance slows down the flow of electrons, and electron flow is the same as current.)
- **What would you need to move the same amount of current through a higher-resistance filament?** (More force or voltage.)

### ● ● ● ● Integration ● ● ● ●

Use the discussion of the resistance of wires to integrate concepts of metals into your lesson.

**Figure 1–21** *This is no magic trick. At low temperatures, certain materials that have almost no resistance are said to be superconducting. Superconducting materials, such as the one at the bottom of the photograph, repel magnets. For this reason the magnet floats in midair.*

ow temperatures, however, the resistance of certain netals becomes essentially zero. Materials in this state are said to be **superconductors.** In supercon-luctors, almost no energy is wasted. However a great deal of energy must be used to keep the naterial cold enough to be superconducting.

Scientists are currently working to develop new naterials that are superconducting at higher temper-atures. When this is accomplished, superconductors will become extremely important in industry. Super-conductors will be used in large generating plants and in motors where negligible resistance will allow for very large currents. There are also plans for superconducting transmission cables that will reduce energy loss tremendously. Electric generating plants 3 are usually located near major population centers rather than near the fuel source because too much energy is lost in carrying a current. Superconducting transmission lines will make it practical for generat-ing plants to be situated next to fuel sources rather than near population centers. Superconductors are also being tested in high-speed transportation systems.

## Ohm's Law

An important expression called **Ohm's Law** iden-tifies the relationship among current, voltage, and resistance. **Ohm's law states that the current in a wire (I) is equal to the voltage (V) divided by the resistance (R).**



ANNOTATION KEY

Integration

1 Physical Science: Metals. See *Matter: Building Block of the Universe*, Chapter 5.

2 Physical Science: Heat. See *Heat Energy*, Chapter 1.

3 Physical Science: Hydroelectric Power. See *Ecology: Earth's Natural Resources*, Chapter 1.

## COMMON ERRORS

While completing computation problems using Ohm's law, students may rearrange the formula in incorrect ways. For example, in solving for V, given I and R, they may divide I by R instead of multiplying the two quantities.

Review the algebra involved in such rearrangements and also analyze the units that result from rearrangements. Demonstrate to students that such dimensional analysis can help to reveal errors in manipulating equations and carrying out calculations.

### GUIDED PRACTICE

**Skills Development**

***Skills: Making comparisons, making diagrams***

Have students plan and execute drawings that illustrate, in their own creative ways, the concepts of voltage, current, and resistance. Before students begin, have them review Figure 1–18, which illustrated the difference between high and low voltage and current situations.

### CONTENT DEVELOPMENT

Have students look at the photograph in Figure 1–21 and speculate on what is causing the magnet to float in midair. Then have a volunteer read the caption. Explain that changes in temperature can affect the resistance of a material.

● ● ● ● **Integration** ● ● ● ●

Use the discussion of the relationship between resistance and temperature to integrate concepts of heat into your lesson.

Use the discussion of superconductors to integrate concepts of hydroelectric power into your lesson.

### CONTENT DEVELOPMENT

Remind students that the ohm is the unit of resistance. Then, after reviewing the concepts of voltage and current, introduce Ohm's law:

$$I = \frac{V}{R}$$

Carry out sample calculations involving this equation in rearranged forms; use it, in separate problems, to solve for I, V, and R. Be sure to pay attention to the units involved and bring out the general point that I and R vary inversely, given a constant V.

ANNOTATION KEY

Answers

1 5 ohms. (Making calculations)

2 No; nothing happens. (Applying concepts)

3 The bulb lights up. (Applying concepts)

4 The light bulb will light up. (Relating cause and effect)

Integration

1 Mathematics

## FIND OUT BY CALCULATING

OHM'S LAW

***Skills: Applying concepts, making calculations, calculator***

Students should use Ohm's law to arrive at the following calculations: Row 1: 0.16 amps; Row 2: 16 ohms; Row 3: 110 volts; Row 4: 0.24 amps; Row 5: 22 ohms.

**Integration:** Use the Find Out by Calculating feature to integrate mathematics into your science lesson.

## 1–3 (continued)

### REINFORCEMENT/RETEACHING

Encourage slower students to carry out many simple practice calculations involving Ohm's law. They can make up charts that show the various correct rearrangements of the equation and that display an assortment of values obtained by substituting different numbers and solving for the unknown.

### INDEPENDENT PRACTICE

**Section Review 1–3**

1. A chemical reaction causes the release of electrons. These electrons flow from a negative terminal to a positive terminal. Then the electrons are pumped back to the negative terminal to begin the cycle again.

2. A thermocouple generates electricity from heat energy by making use of temperature differences. A photocell converts light energy into electrical energy.

3. Electric current is the rate of flow of electrons. When the wire is connected to a source of electricity, electrons are pulled away from their atoms and are then free to move through the wire.

4. Resistance is the opposition to the flow of electricity. Voltage is the energy available to move electrons.

5. The flow of electrons continuously in the same direction; the flow of electrons back and forth so that their direction is regularly reversed.

6. The chemicals in the dry cell are eventually used up as a result of continuous chemical reaction.

### REINFORCEMENT/RETEACHING

Review students' responses to the Section Review questions. Reteach any material that is still unclear, based on students' responses.

## FIND OUT BY CALCULATING

*Ohm's Law*

Complete the following chart.

1

| I (amps) | V (volts) | R (ohms) |
|---|---|---|
| | 12 | 75 |
| 15 | 240 | |
| 5.5 | | 20 |
| | 6 | 25 |
| 5 | 110 | |

As an equation, Ohm's Law is

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

$$I = \frac{V}{R} \qquad \text{Amperes} = \frac{\text{Volts}}{\text{Ohms}}$$

If the resistance in a wire is 100 ohms and the voltage is 50 volts, the current is 50/100, or 0.5 ampere. You can rearrange the equation in order to calculate resistance or voltage. What is the resistance if the voltage is 10 volts and the current 2 amperes?

## Current Direction

Electrons moving through a wire can move continuously in the same direction, or they can change direction back and forth over and over again.

When electrons always flow in the same direction, the current is called **direct current,** or DC. Electricity from dry cells and batteries is direct current.

When electrons move back and forth, reversing their direction regularly, the current is called **alternating current,** or AC. The electricity in your home is alternating current. In fact, the current in your home changes direction 120 times every second. Although direct current serves many purposes, alternating current is better for transporting the huge amounts of electricity required to meet people's needs.

## 1–3 Section Review

1. How does an electrochemical cell produce an electric current?
2. What is a thermocouple? A photocell?
3. What is electric current? Explain how current flows through a wire.
4. What is resistance? Voltage? How is electric current related to resistance and voltage?
5. What is direct current? Alternating current?

**Critical Thinking—*Drawing Conclusions***

6. If the design of a dry cell keeps electrons flowing steadily, why does a dry cell go "dead"?

# 1–4 Electric Circuits

**Guide for Reading**

*Focus on these questions as you read.*

- *What is an electric circuit?*
- *What is the difference between series and parallel circuits?*

Perhaps you wonder why electricity does not flow from the outlets in your home at all times? You can find the answer to this question if you try the following experiment. Connect one wire from a terminal on a dry cell to a small flashlight bulb. Does anything happen? Now connect another wire from the bulb to the other terminal on the dry cell. What happens? With just one wire connected, the bulb will not light. But with two wires providing a path for the flow of electrons, the bulb lights up.

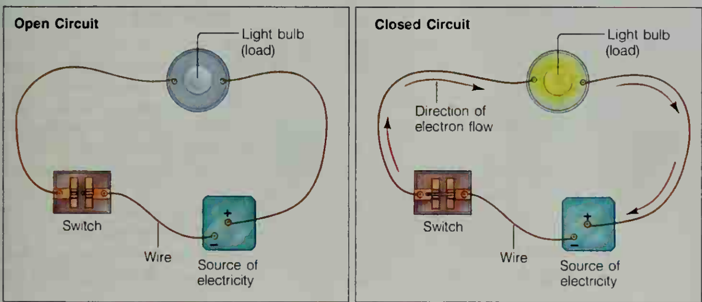
In order to flow, electrons need a closed path through which to travel. **An electric circuit provides a complete, closed path for an electric current.**

## Parts of a Circuit

An electric circuit consists of a source of energy; a load, or resistance; wires; and a switch. Recall that the source of energy can be a battery, a thermocouple, a photocell, or an electric generator at a power plant.

The load is the device that uses the electric energy. The load can be a light bulb, an appliance, a machine, or a motor. In all cases the load offers some resistance to the flow of electrons. As a result, electric energy is converted into heat, light, or mechanical energy.

**Figure 1–22** *No electricity can flow through an open circuit (left). When the switch is flipped, the circuit is closed and electrons have a complete path through which to flow (right). What indicates that a current is flowing through the circuit?* 4




# 1-4 Electric Circuits

## MULTICULTURAL OPPORTUNITY 1-4

Have your students investigate the life and work of the African-American inventor Lewis Howard Latimer (1848–1928). Latimer, the only African-American member of the Edison Pioneers, was instrumental in the development of the electric light bulb. As a draftsman, Latimer was responsible for developing the blueprints necessary for Thomas Alva Edison to receive his patents. He was also frequently called upon to defend Edison's patent claims in court—a task which he did ably because of his vast knowledge of electricity. In 1890, he published a book entitled *Incandescent Electric Lighting*.

## ESL STRATEGY 1-4

Ask students to change the underlined word in each of the following sentences so that the statements are true.

- Electricity cannot flow through a closed circuit. (Answer: can.)
- Electricity can flow through an open circuit. (Answer: cannot.)

## CONTENT DEVELOPMENT

Reintroduce students to the circuit parts with which they are already familiar. Then discuss the nature of a circuit and the fact that circuits must be closed. Ask them to observe the circuits shown in Figure 1–22, which helps to make this fact clear.

## GUIDED PRACTICE

### Skills Development

***Skills: Applying concepts, making observations, making comparisons***

Have students complete the in-text Chapter 1 Laboratory Investigation: Electricity From a Lemon. In the investigation students will explore the flow of electricity created by a simple wet cell.

## ENRICHMENT

▶ *Activity Book*

Students can build another simple wet cell in the chapter 1 activity called Electricity From an Olive.

## CLOSURE

▶ *Review and Reinforcement Guide*

Have students complete Section 1–3 in the *Review and Reinforcement Guide*.

## TEACHING STRATEGY 1-4

## FOCUS/MOTIVATION

Show students a simple electric circuit containing a small light bulb, a low-voltage dry cell, wires, and a switch. Open and close the switch several times and encourage students to do so as well.

- **What is happening?** (Electrons are flowing from one terminal of the dry cell, through a closed circuit, back to the other terminal.)
- **What happens when the switch is opened? Why?** (Current can no longer flow because there is no longer a complete, closed path for electrons to travel along.)

## BACKGROUND INFORMATION

### CONDUCTANCE

The conductance of a direct current circuit is the reciprocal of its resistance. Conductance is usually represented by the letter G.

$$G = \frac{1}{R}$$

Conductance is used to help calculate the total resistance of a parallel circuit. One unit for conductance is the mho—ohm spelled backwards!

## HISTORICAL NOTE

### ST. ELMO'S FIRE

St. Elmo's Fire is a glow or a flame sometimes seen on the masts of ships during stormy weather. Also called corona discharge, St. Elmo's Fire is caused by the ionization of the air surrounding the tip of the mast. The color of the ionization is a function of the energy of the ions. Different materials require different energy levels to ionize, and thus result in different colors.

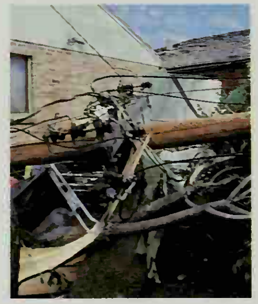


**Figure 1–23** *When severe weather conditions—such as the tornado that caused this destruction—damage power lines, the flow of electricity is interrupted. Why?* 1

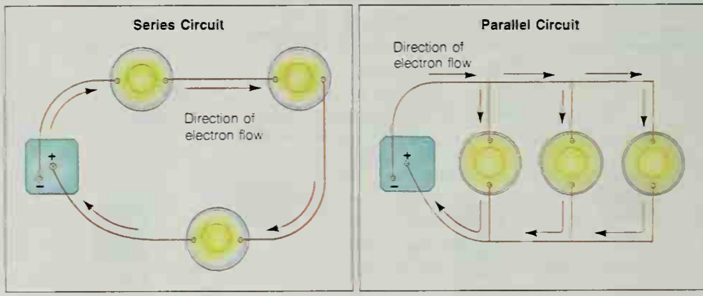
The switch in an electric circuit opens and closes the circuit. You will remember that electrons cannot flow through a broken path. Electrons must have a closed path through which to travel. When the switch of an electric device is off, the circuit is open and electrons cannot flow. When the switch is on, the circuit is closed and electrons are able to flow. Remember this important rule: *Electricity cannot flow through an open circuit. Electricity can flow only through a closed circuit.*

### Series and Parallel Circuits

There are two types of electric circuits. The type depends on how the parts of the circuit (source, load, wires, and switch) are arranged. If all the parts of an electric circuit are connected one after another, the circuit is a **series circuit.** In a series circuit there is only one path for the electrons to take. Figure 1–24 illustrates a series circuit. The disadvantage of a series circuit is that if there is a break in any part of the circuit, the entire circuit is opened and no current can flow. Inexpensive holiday tree lights are often connected in series. What will happen if one light goes out in a circuit such as this?

In a **parallel circuit,** the different parts of an electric circuit are on separate branches. There are several paths for the electrons to take in a parallel circuit. Figure 1–24 shows a parallel circuit. If there is a break in one branch of a parallel circuit, electrons can still move through the other branches. The

**Figure 1–24** *A series circuit provides only one path for the flow of electrons. A parallel circuit provides several paths. How are the circuits in your home wired? Why?* 3






## 1–4 (continued)

### CONTENT DEVELOPMENT

When you introduce series and parallel circuits, direct students' attention to Figure 1–24, which brings out the difference between the two types of circuits. If possible, construct actual series and parallel circuits in the classroom.

Ask students to make their own diagrams of series and of parallel circuits. They can use colored pencils to trace the various paths of electrons. More advanced students can also do library research on the voltage, current, and resistance relationships for the two types of circuits and can include their findings in the chart.

▶ *Multimedia* ◀

Use the transparency in the *Transparency Binder* called Series and Parallel Circuits to help students understand the concepts in this section.

### INDEPENDENT PRACTICE

▶ *Activity Book*

Students who need practice with series and parallel circuits should be provided with the Chapter 1 activity called Electric Circuitry.

### GUIDED PRACTICE

▶ *Laboratory Manual*

**Skills Development**

***Skills: Applying concepts, making observations, making comparisons, making inferences***

At this point you may want to have students complete the Chapter 1 Laboratory Investigation in the *Laboratory Manual* called Building Electric Circuits. In the investigation students will explore both series and parallel circuits.

current continues to flow. Why do tree lights connected in parallel have an advantage over tree lights connected in series? Why do you think the electric circuits in your home are parallel circuits? 4

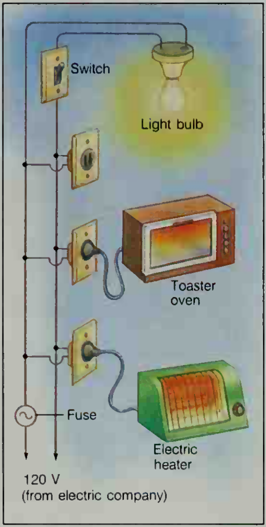
## Household Circuits

Have you ever wondered what was behind the outlet in the wall of your home? After all, it is rather amazing that by inserting a plug into the wall outlet, you can make your television, refrigerator, vacuum cleaner, hair dryer, or any other electrical appliance operate.

Connected to the outlet is a cable consisting of three wires enclosed in a protective casing. Two of the wires run parallel to each other and have a potential difference of 120 volts between them. The third wire is connected to ground. (Recall that a wire that is grounded provides the shortest direct path for current to travel into the Earth.) For any appliance in your home to operate, it must have one of its terminals connected to the high potential wire and the other terminal connected to the low potential wire. The two prongs of a plug of an appliance are connected to the terminals inside the appliance. When the switch of the appliance is closed, current flows into one prong of the plug, through the appliance, and back into the wall through the other prong of the plug.

Many appliances have a third prong on the plug. This prong is attached to the third wire in the cable, which is connected directly to ground and carries no current. This wire is a safety feature to protect against short circuits. A short circuit is an accidental connection that allows current to take a shorter path around a circuit. A shorter path has less resistance and therefore results in a higher current. If the high-potential wire accidentally touches the metal frame of the appliance, the entire appliance will become part of the circuit and anyone touching the appliance will suffer a shock. The safety wire provides a shorter circuit for the current. Rather than flowing through the appliance, the current will flow directly to ground—thereby protecting anyone who might touch the appliance. Appliances that have a plastic casing do not need this safety feature. Can you explain why? 6

**Figure 1–25** *The outlets in a home are connected in such a way that several may rely on the same switch. A home must have several circuits so that different switches control only certain outlets. What happens when the switch in the diagram is flipped off? What if all the appliances in the home are attached to this circuit?* 5






### ANNOTATION KEY

**Answers**

1 Damage to wires means that the circuits are no longer closed. Thus the electric current cannot flow. (Applying concepts)

2 All the lights on the string will go out because there is no longer a complete, closed path. (Applying concepts)

3 The circuits are wired in parallel so that if one circuit is opened, the others remain closed and electricity can still flow. (Relating cause and effect)

4 So that a problem on one circuit will not cause all the electricity in the entire house to go off. (Making inferences)

5 None of the appliances are working; a problem in any one appliance could cause them all to stop working. (Interpreting diagrams)

6 Plastic is a poor conductor of electricity. (Making inferences)

### FACTS AND FIGURES

**ALTERNATING CURRENT**

The rate at which alternating current varies is expressed in cycles per second. One cycle per second is called one hertz. The domestic power supply in the United States alternates at the rate of 60 hertz. The same rate is not used worldwide.

### ENRICHMENT

Advanced students can be encouraged to do library research on other devices, such as capacitors, used in electronic circuits. They can also find out about the symbols for the various circuitry elements that are used in schematic diagrams.

### REINFORCEMENT/RETEACHING

Remind students that there are two basic types of electrical current. The current from a dry cell or battery is called direct current (DC) because the current of electrons flows in only one direction. The current in houses and schools is called alternating current (AC) because the current alternates and reverses directions many times a second. An alternating current is a current in which electrons change direction at regular intervals. Point out that most of the current students use is alternating current.

### CONTENT DEVELOPMENT

Divide the class into teams of three to six students. Show students some common electrical appliances, such as a light bulb, blow dryer, heating pad, fan, and/or steam iron. Point out that most electrical appliances are rated according to the line voltage needed and the power consumed in watts. Mention that these figures normally can be found on a side plate on appliances and on the top of a light bulb.

Distribute an appliance to each team. Have the teams find, read, and record the name of the appliance, voltage, and watts or amps. Have the teams exchange appliances until each team has had a chance to record the data from each appliance.

ANNOTATION KEY

Answers

1 A strip of metal in the fuse melted, breaking the electric circuit. This prevented too much heat from building up on wires in the circuit. (Relating cause and effect)

## PROBLEM SOLVING

### FAULTY WIRING

In this activity students will have a chance to do some creative detective work. Before assigning the Problem Solving feature, it may be useful to review the topic of series and parallel circuits.

Students should realize that Ms. Fix-It must have wired the cabin using series circuits. As a result, the cabin has some inconvenient peculiarities. In order to solve these inconveniences, the wiring will have to be redone using one or more parallel circuits. This will allow visitors to use each electrical appliance on its own.

After students have completed their diagrams and the class has discussed their solutions, point out that correcting problems in electrical wiring can be much more complicated than installing new wiring. Both processes can be dangerous for the amateur. The family described in the Problem Solving feature might be well advised to call on the services of a qualified electrician.

**Figure 1–26** *Fuses protect circuits from overloading. The fuse on the left is new. The fuse on the right, however, has been blown and cannot be blown again. How did the blown fuse protect the circuit it was part of?* 1

## Circuit Safety Features

Your home has a great amount of electricity running through it. If too many appliances are running at once on the same circuit or if the wires have become old and frayed, heat can build up in the wiring. If the wires in the walls get too hot, there is the danger of fire. Two devices protect against this potential danger.

**FUSES** To protect against too much current flowing at once, your home may have **fuses** in a fuse box. Inside each fuse is a thin strip of metal through which current flows. If the current becomes too high, the strip of metal melts and breaks the flow of electricity. So a fuse is an emergency switch.

**CIRCUIT BREAKERS** One disadvantage of fuses is that once they burn out, they must be replaced. For this reason, **circuit breakers** are often used instead of fuses. Like fuses, circuit breakers protect a circuit from becoming overloaded. Modern circuit breakers have a switch that flips open when the current flow becomes too high. These circuit breakers can easily be reset and used again once the problem has been found and corrected. Circuit breakers are easier to use than fuses.

### 1–4 Section Review

1. What is an electric circuit?
2. Compare a series circuit and a parallel circuit.
3. Can a circuit be a combination of series connections and parallel connections? Explain your answer.
4. What would happen if your home were not wired in parallel?

**Connection—*You and Your World***

5. Does your home have fuses or circuit breakers? Explain the purpose of each device.



### 1–4 (continued)

CONTENT DEVELOPMENT

Point out that a fuse is a safety device installed in an electric circuit. Explain that fuses prevent overloading of a circuit. In a house and other buildings, each circuit has a fuse or circuit breaker. Separate fused circuits allow the rest of the circuits to remain undisturbed, even if one circuit goes out.

REINFORCEMENT/RETEACHING

▶ *Multimedia* ◀

Students may review the concepts in this section by using the video called Electric Currents and Circuits.

After students have seen the video, have them list several examples of each of the following (possible responses are given in parentheses).

**1.** Electric energy is converted into light. (Light bulbs used in homes and businesses, street lights, automobile headlights.)

**2.** Electric energy is converted into motion. (Kitchen blender or mixer, electric drill, electric saw.)

**3.** Electric energy is converted into heat. (Heat in a light bulb, electric heaters, heat in electric wires.)

**4.** Electric energy is converted into sound. (Stereo system or record player, sound created by electric motors, doorbell.)

# Problem Solving

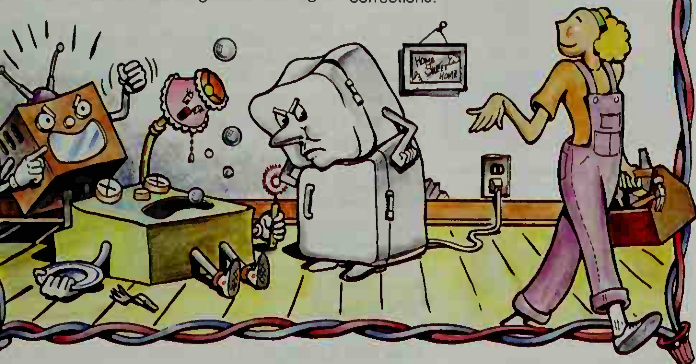
## Faulty Wiring

You and your family arrive at the site of your summer vacation—an old but quaint cabin situated at the edge of a beautiful lake. As you pile out of the car, you are greeted by the superintendent responsible for taking care of all the cabins in the area. The neighbors call her Ms. Fix-It.

Ms. Fix-It tells you that everything in the cabin is in working order. However, when she was working on the wiring, she must have made a mistake or two. The kitchen light must remain on in order to keep the refrigerator going. In order to turn on the television, the fan must be on. And the garbage disposal will work only when the oven is on.

**Drawing Diagrams**

How must the cabin be wired? How should the cabin be rewired? Draw a diagram showing the mistakes and the corrections.



## 1–5 Electric Power

**Guide for Reading**

*Focus on these questions as you read.*

- *What is electric power?*
- *How is electric power related to energy?*

You probably use the word power in a number of different senses—to mean strength, or force, or energy. To a scientist, **power** is the rate at which work is done or energy is used. **Electric power is a measure of the rate at which electricity does work or provides energy.**



# 1–5 Electric Power

### MULTICULTURAL OPPORTUNITY 1–5

Have your students read their electric meter each day, at the same time of day, for one week. Next they should plot the electrical usage per day over the one-week period. Are there some days when they use more electricity? If so, what explanations can they generate for this increased use?

### ESL STRATEGY 1–5

Have students create a six-frame illustration of the safety rules of electricity. They should number each frame to match the rules listed in this section.

### REINFORCEMENT/RETEACHING

Review students' responses to the Section Review questions. Reteach any material that is still unclear, based on students' responses.

### CLOSURE

▶ *Review and Reinforcement Guide*

Have students complete Section 1–4 in the *Review and Reinforcement Guide*.

### INDEPENDENT PRACTICE

**Section Review 1–4**

1. A complete, closed path for the flow of electrons.
2. In a series circuit, there is only one path for electron flow. In a parallel circuit, there are several paths.
3. Yes. Separate sections of a circuit could be in parallel but be connected to one another in series. Also, separate sections could be connected in series, but be connected to one another in parallel.
4. If one light or appliance went off, all the others would not work.
5. Answers will vary. In a fuse, a strip of metal melts when the current is too high. In a circuit breaker, a switch turns off if too much current flows through a circuit.

## TEACHING STRATEGY 1–5

### FOCUS/MOTIVATION

Ask students, in advance, to bring in (with their parents' permission) an electric utility bill. In class, explain that the information stated on the bill and the price of service relates to the quantity of electric energy used, which in turn depends on voltage, current, and time. As you go on to teach students the specifics regarding electric power and energy, explain in more detail how knowledge about these quantities and their calculations can be used to understand the information on their utility bills.

## HISTORICAL NOTE

### JAMES WATT

The unit for measuring electric power, the watt, is named after the British engineer James Watt (1736–1819). Watt was a successful inventor of many things, but his most famous work was in the development of the steam engine. In the mid–1700s, he took an interest in the Newcomen steam engine, and he set about making it more efficient. Working together with Matthew Boulton, Watt created an experimental engine embodying the essential characteristics of the modern steam engine.

**POWER USED BY COMMON APPLIANCES**

| Appliance | Power Used (watts) |
|---|---|
| Refrigerator/ freezer | 600 |
| Dishwasher | 2300 |
| Toaster | 700 |
| Range/oven | 2600 |
| Hair dryer | 1000 |
| Color television | 300 |
| Microwave oven | 1450 |
| Radio | 100 |
| Clock | 3 |
| Clothes dryer | 4000 |

**Figure 1–27** *The table shows the power used by some common appliances. Which appliance would use the greatest amount of electric energy if operated for one hour?* 1

If you can, pick up a cool light bulb and examine it. Do you notice any words written on it? For example, do you see "60 watts" or "100 watts" on the bulb? Watts (W) are the units in which electric power is measured. To better understand the meaning of watts, let's look at the concept of electric power more closely.

As you have just read, electric power measures the rate at which electricity does work or provides energy. Electric power can be calculated by using the following equation:

$$\textbf{Power} = \textbf{Voltage} \times \textbf{Current}$$
or
$$\textbf{P} = \textbf{V} \times \textbf{I}$$

Or, put another way:

$$\textbf{Watts} = \textbf{Volts} \times \textbf{Amperes}$$

Now think back to the light bulb you looked at. The electricity in your home is 120 volts. The light bulb itself operates at 0.5 ampere. According to the equation for power, multiplying these two numbers gives the bulb's wattage, which in this case is 60 watts. The wattage tells you the power of the bulb, or the rate at which energy is being delivered. As you might expect, the higher the wattage, the brighter the bulb—and the more expensive to run.

To measure large quantities of power, such as the total used in your home, the kilowatt (kW) is used. The prefix *kilo-* means 1000. So one kilowatt is 1000 watts. What is the power in watts of a 0.2-kilowatt light bulb? 2

## Electric Energy

Have you ever noticed the electric meter in your home? This device measures how much energy your household uses. The electric company provides electric power at a certain cost. Their bill for this power is based on the total amount of energy a household uses, which is read from the electric meter.

The total amount of electric energy used depends on the total power used by all the electric appliances



## 1–5 (continued)

### CONTENT DEVELOPMENT

Explain that the unit of power is stated in watts when the force is in volts and the current is in amperes. Have students examine Figure 1–27. Discuss the power ratings of the appliances and encourage students to compare the appliances listed.

• **Which appliance listed uses the least number of watts?** (The clock.)

Show the class how to use the equations below to find watts, volts, and amperes. Write the following equations on the chalkboard.

Power = Force × Current
Watts = Volts × Amperes
Volts = Watts ÷ Amperes
Amperes = Watts ÷ Volts

### Integration

Use the discussion of watts to integrate concepts of power into your lesson.

### GUIDED PRACTICE

**Skills Development**

***Skill: Making calculations***

Have students solve the following problems. Remind students to use the proper units of measure.

• **What is the current used by an electric iron marked 120 volts and 1000 watts?** (1000/120 = 8.33 amps.)

• **How much power is used by a light bulb marked 0.45 amps and 110 volts?** (49.5 watts.)

• **What voltage is needed for an electric clothes dryer marked 880 watts at a current of 4 amps?** (220 volts.)

### CONTENT DEVELOPMENT

Explain that a watt is the power required to keep a current of 1 ampere flowing in a circuit under a pressure of 1 volt. Refer to the textbook discussion, which states that because a watt is a small unit, power, or electric energy, is usually measured in kilowatts. One kilowatt is equal to 1000 watts.

### REINFORCEMENT/RETEACHING

Hyphenated units, such as the kilowatt-hour, are often misunderstood by students, who mistake the hyphen for a minus sign and imagine that the connected units are to be subtracted. Make it clear to students that hyphens in units

**Figure 1–28** *Electricity for your home is purchased on the basis of the amount of energy used and the length of time for which it is used. Power companies install an electric meter in your home to record this usage in kilowatt-hours.*

and the total time they are used. The formula for electric energy is

$$\text{Energy} = \text{Power} \times \text{Time}$$
or
$$E = P \times t$$

Electric energy is measured in kilowatt-hours (kWh).

$$\text{Energy} = \text{Power} \times \text{Time}$$
$$\text{Kilowatt-hours} = \text{Kilowatts} \times \text{Hours}$$

One kilowatt-hour is equal to 1000 watts of power used for one hour of time. You can imagine how much power this is by picturing ten 100-watt bulbs in a row, all burning for one hour. One kilowatt-hour would also be equal to a 500-watt appliance running for two hours.

To pay for electricity, the energy used is multiplied by the cost per kilowatt-hour. Suppose the cost of electricity is $0.08 per kilowatt-hour. How much would it cost to burn a 100-watt bulb for five hours? To use a 1000-watt air conditioner for three hours? 3

## Electric Safety

Electricity is one of the most useful energy resources. But electricity can be dangerous if it is not used carefully. Here are some important rules to remember when using electricity.

**1.** Never handle appliances when your hands are wet or you are standing in water. Water is a fairly good conductor of electricity. If you are wet, you could unwillingly become part of an electric circuit.

**2.** Never run wires under carpets. Breaks or frays in the wires may go unnoticed. These breaks cause short circuits. A short circuit represents a shorter and easier path for electron flow and thus can cause shocks or a fire.

### FIND OUT BY THINKING

*Power and Heat*

Examine the appliances in your home for their power rating. Make a chart of this information.

- What is the relationship between an appliance's power rating and the amount of heat it produces?



### ANNOTATION KEY

**Answers**

1 The range or oven. (Interpreting charts)

2 200 watts. (Making calculations)

3 $0.04; $0.24. (Making calculations)

**Integration**

1 Physical Science: Power. See *Motion, Forces, and Energy*, Chapter 4.

### FIND OUT BY THINKING

POWER AND HEAT

**Discovery Learning**

***Skills: Applying concepts, recording data, making comparisons, making inferences***

Students should be able to include the power ratings of various appliances on a chart and infer that those with the highest power rating often produce the most heat.

### ECOLOGY NOTE

ENERGY CONSERVATION

Increasingly, manufacturers are providing energy-usage information to help consumers choose more energy-efficient appliances. Refrigerators, freezers, water heaters, and air conditioners make use of new technologies to cut down on inefficient energy use.

Improvements in efficiency in electric power generation are also being implemented. For example, cogeneration is a process that uses a jet engine and a conventional boiler one after the other. Another promising technology is called magnetohydrodynamics. This process involves seeding combustion gases with potassium.

actually represent multiplication of units.

### CONTENT DEVELOPMENT

You can easily demonstrate the validity of the $E = P \times t$ equation by noting that power is simply energy divided by time. Thus the right side of the equation, $P \times t$, reduces to

$$\frac{\text{Energy}}{\text{time}} \times \text{time}$$

which clearly equals energy.

### INDEPENDENT PRACTICE

▶ *Activity Book*

Students can investigate the ways in which people protect themselves against sudden power failures in the Chapter 1 activity called Emergency Power Sources.

## FIND OUT BY CALCULATING

HOW MUCH ELECTRICITY DO YOU USE?

***Skills: Applying concepts, making comparisons, making calculations, calculator***

Students will be able to get a practical understanding of the cost of electricity through this simple activity. They will also have to relate the concepts and equations presented in the textbook to make their calculations. You may want to call the local power company yourself and inform students of the cost of electricity per kilowatt-hour in your area.

## BACKGROUND INFORMATION

SAFETY STANDARDS

Government agencies, both local and national, provide information and enforce regulations to help ensure electric safety in homes and industries. The National Electric Code is a national set of standards for home and industrial installations. Local communities also have specific regulations, which are administered through a housing, building, or wiring inspector. In some communities, all wiring must be done by a licensed electrician, even in private homes.

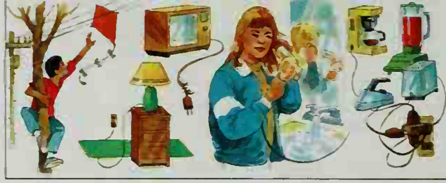


**Figure 1–29** *Remember to exercise care and good judgment when using electricity. Avoid unsafe conditions such as the ones shown here.*

**3.** Never overload a circuit by connecting too many appliances to it. Each electric circuit is designed to carry a certain amount of current safely. An overloaded circuit can cause a short circuit.

**4.** Always repair worn or frayed wires to avoid short circuits.

**5.** Never stick your fingers in an electric socket or stick a utensil in an appliance that is plugged in. The electricity could be conducted directly into your hand or through the utensil into your hand. Exposure to electricity with both hands can produce a circuit that goes through one arm, across the heart, and out the other arm.

**6.** Never come close to wires on power poles or to wires that have fallen from power poles or buildings. Such wires often carry very high currents.

### FIND OUT BY CALCULATING

*How Much Electricity Do You Use?*

**1.** For a period of several days, keep a record of every electrical appliance you use. Also record the amount of time each appliance is run.

**2.** Write down the power rating for each appliance you list. The power rating in watts should be marked on the appliance. You can also use information in Figure 1-27.

**3.** Calculate the amount of electricity in kilowatt-hours that you use each day.

**4.** Find out how much electricity costs per kilowatt-hour in your area. Calculate the cost of the electricity you use each day.

### 1–5 Section Review

1. What is electric power? What is the formula for calculating electric power? In what unit is electric power measured?
2. What is electric energy? What is the formula for calculating electric energy? In what unit is electric energy measured?
3. What happens if you touch an exposed electric wire? Why is this situation worse if you are wet or standing in water?

**Critical Thinking—*Making Calculations***

4. If left running unused, which appliance would waste more electricity, an iron left on for half an hour or a television left on for one hour?



## 1–5 (continued)

### ENRICHMENT

▶ *Activity Book*

Students who have mastered the concepts in this section will be challenged by the Chapter 1 activity called Electric Math.

### CONTENT DEVELOPMENT

Take sufficient time to deal with principles involving electric safety. Review the rules given and ask students to come up with others. Finally, remind students of the role of fuses and circuit breakers and encourage students to learn the location of these devices in their homes.

### GUIDED PRACTICE

**Skills Development**

***Skill: Applying concepts***

Ask students to analyze their homes in terms of the electric safety rules discussed. They should check to see that none of the relevant rules is violated. If there are any potential difficulties, students should record what the problems are and how they might result in a dangerous situation. Students should then inform their parents and should see to it that the problems are corrected.

### ENRICHMENT

Benjamin Franklin believed that substances contained what he called "electric fluid." He thought that friction between objects, such as that between rubber and fur or between clouds, removed some of the "fluid" from one object, causing it to be deficient in the "fluid," and transferred it to the other,

# CONNECTIONS

## Electrifying Personalities ❶

Your hair color, eye color, height, and other personal traits are not the haphazard results of chance. Instead, they are determined and controlled by a message found in every one of your body cells. The message is referred to as the *genetic code.* The genetic information passed on from generation to generation in all living things is contained in structures called chromosomes, which are made of genes.

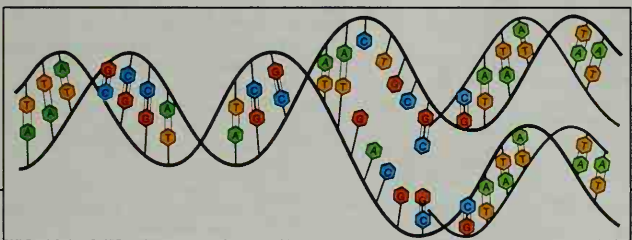
The genetic information contained in a gene is in a molecule of DNA (deoxyribonucleic acid). A DNA molecule consists of a long chain of many small molecules known as nucleotide bases. There are only four types of bases in a DNA molecule: adenine (A), cytosine (C), guanine (G), and thymine (T). The order in which the bases are arranged determines everything about your body.

A chromosome actually consists of two long DNA molecules wrapped around each other in the shape of a double helix. The two strands are held together in a precise shape by electric forces—the attraction of positive charges to negative charges.

In addition to holding the two strands of DNA together, electric forces are responsible for maintaining the genetic code and reproducing it each time a new cell is made. Your body is constantly producing new cells. It is essential that the same genetic message be given to each cell. When DNA is reproduced in the cell, the two strands unwind, leaving the charged parts of the bases exposed. Of the four bases, only certain ones will pair together. A is always paired with T, and G is always paired with C.

Suppose, for example, that after DNA unwinds, a molecule of C is exposed. Of the four bases available for pairing with C, only one will be electrically attracted to C. The charges on the other three bases are not arranged in a way that makes it possible for them to get close enough to those on C.

Electric forces not only hold the two chains together, they also operate to select the bases in proper order during reproduction of the genetic code. Thus the genetic information is passed on accurately to the next generation. So, although it may surprise you, it is a fact: Electricity is partly responsible for your features, from your twinkling eyes to your overall size.



ANNOTATION KEY

Integration

❶ Life Science: Genetics. See *Heredity: The Code of Life*, Chapter 2.

CONNECTIONS

ELECTRIFYING PERSONALITIES

By the late 1970s, molecular biologists had learned how to determine the bases on a given segment of DNA; that is, they had learned how to "read" DNA. The base sequence is the same in all humans for 99.9 percent of the DNA. The variations determine the differences between individual human beings.

Using restriction enzymes, gene engineers have been able to cut out genes from human DNA and splice them into bacteria for mass production of human proteins. These proteins are then used to cure or prevent disease. Examples include insulin for diabetes and interferon for some forms of cancer.

Students may already be familiar with the genetic information contained in DNA from other science courses or articles in the popular press.

If you are teaching thematically, you may want to use the Connections feature to reinforce the themes of systems and interactions or patterns of change.

**Integration:** Use the Connections feature to integrate genetics into your science lesson.

causing it to have an excess of the "fluid." He theorized that these differences created the conditions for electrical attraction and repulsion. His theories, although crude, helped to pave the way for progress in the understanding of electricity.

INDEPENDENT PRACTICE

Section Review 1–5

1. The rate at which electricity does work or provides energy; $P = V \times I$; watt.

2. The total power used by appliances operating for a certain length of time; $E = P \times t$; kilowatt-hour.

3. You may receive an electric shock. The electricity will go through one arm, across the heart, and out through your body. Water is a fairly good conductor of electricity.

4. Accept all reasonable answers. The amount of electricity will depend on the power used by the two appliances.

REINFORCEMENT/RETEACHING

Review students' responses to the Section Review questions. Reteach any material that is still unclear, based on students' responses.

CLOSURE

▶ *Review and Reinforcement Guide*

Have students complete Section 1–5 in the *Review and Reinforcement Guide.*

# Laboratory Investigation

## ELECTRICITY FROM A LEMON

### BEFORE THE LAB

1. Gather all materials at least one day prior to the investigation. You should have enough supplies to meet your class needs, assuming six students per group.
2. For motivation purposes, you may wish to allow students to bring in their own coins and lemons.

### PRE-LAB DISCUSSION

Quickly review the basic concepts of electricity, such as current and the electric circuit. Ask students to propose and to discuss hypotheses regarding what will occur during the investigation and why it will occur. Ask them also to consider what experimental findings will support or refute the hypotheses. Also, before they carry out the investigation, warn them not to oversand the coins, as they may expose base metal by doing so.

### SAFETY TIPS

Remind students to be careful using scissors. Also, tell them that juice from lemons that are used in the experiment should not be consumed, as metal salts have become dissolved in the juice.

# Laboratory Investigation

## Electricity From a Lemon

### Problem

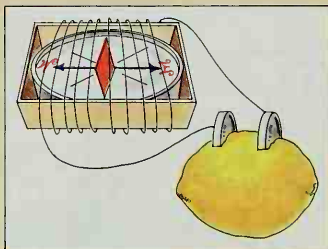
Can electricity be produced from a lemon, a penny, and a dime?

### Materials *(per group)*

| | |
|---|---|
| bell wire | scissors |
| cardboard box | sandpaper |
| compass | dime |
| lemon | 2 pennies |

### Procedure

1. Wrap 20 turns of bell wire around the cardboard box containing the compass, as shown in the accompanying figure.
2. Roll the lemon back and forth on a table or other flat surface while applying slight pressure. The pressure will break the cellular structure of the lemon.
3. Use the pointed end of the scissors to make two slits 1 cm apart in the lemon.
4. Sandpaper both sides of the dime and two pennies.
5. Insert the pennies in the two slits in the lemon as shown in the figure.



6. Touch the two ends of the bell wire to the coins. Observe any deflection of the compass needle.
7. Replace one of the pennies with the dime. Repeat step 6. Observe any deflection of the compass needle. If there is deflection, observe its direction.
8. Reverse the connecting wires on the coins. Observe any deflection of the compass needle and the direction of deflection.

### Observations

1. Is the compass needle deflected when the two ends of the bell wire touch the two pennies?
2. Is the compass needle deflected when the two ends of the bell wire touch the penny and the dime?
3. Is the direction of deflection changed when the connecting wires on the coins are reversed?

### Analysis and Conclusions

1. A compass needle will be deflected in the presence of an electric current. Is an electric current produced when two pennies are used? When a dime and a penny are used?
2. What is the purpose of breaking the cellular structure of the lemon? Of sandpapering the coins?
3. What materials are necessary to produce an electric current?
4. An electric current flowing through a wire produces magnetism. Using this fact, explain why a compass is used in this investigation to detect a weak current.
5. A dime is copper with a thin outer coating of silver. What would happen if the dime were sanded so much that the copper were exposed?



### TEACHING STRATEGY

1. Have the teams follow the directions carefully as they work in the laboratory.
2. If you like, a voltmeter can be used instead of the compass and wire. If so, step 1 can be omitted.
3. It is important that the coins are sandpapered enough to remove any grease and any oxidation residue. Too much sanding, however, will expose only copper, and the metals will not be different.

### DISCOVERY STRATEGIES

Discuss how the investigation relates to the chapter ideas by asking open questions similar to the following:

- **Do you think it is possible to set up an electric current between two coins of the same type? Why or why not?** (No. There is no possible way of creating a potential difference, and thus no current will flow—applying concepts.)
- **How might you use a light bulb instead of the compass in this investigation?** (Accept all logical responses. Students may suggest creating a circuit in which a lighted bulb would indicate a flow of current—making inferences.)
- **What other fruits or vegetables might be used instead of the lemon? Explain your choices.** (Students may suspect that it is the acid in the lemon that is acting as the electrolyte. They might suggest other fruits with acids such as limes, grapefruits, and so on—making inferences.)

# Study Guide

## Summarizing Key Concepts

### 1–1 Electric Charge

▲ All matter is made of atoms. Atoms contain positively charged protons, negatively charged electrons, and neutral neutrons.

▲ Opposite charges exert a force of attraction on each other. Similar charges exert a force of repulsion.

### 1–2 Static Electricity

▲ A neutral object can acquire charge by friction, conduction, or induction.

▲ The buildup of electric charge is called static electricity.

### 1–3 The Flow of Electricity

▲ Electric charges can be made to flow by a source such as a battery, thermocouple, photocell, or electric generator.

▲ The flow of electrons through a wire is called electric current (I). Electric current is measured in units called amperes (A).

▲ A measure of the potential difference across a source is voltage (V), which is measured in units called volts (V).

▲ Opposition to the flow of charge is called resistance (R). Resistance is measured in units called ohms ($\Omega$).

▲ Ohm's law states that the current in a wire is equal to voltage divided by resistance.

▲ In direct current (DC), electrons flow in one direction. In alternating current (AC), electrons reverse their direction regularly.

### 1–4 Electric Circuits

▲ An electric circuit provides a complete closed path for an electric current. Electricity can flow only through a closed circuit.

▲ There is only one path for the current in a series circuit. There are several paths in a parallel circuit.

### 1–5 Electric Power

▲ Electric power measures the rate at which electricity does work or provides energy. The unit of electric power is the watt (W).

## Reviewing Key Terms

*Define each term in a complete sentence.*

### 1–1 Electric Charge

atom
proton
neutron
electron
charge
force
electric field

### 1–2 Static Electricity

friction
conduction
conductor
insulator
induction
static electricity
electric discharge
electroscope

### 1–3 The Flow of Electricity

battery
potential difference
thermocouple
photocell
circuit
current
voltage
resistance
superconductor
Ohm's law
direct current
alternating current

### 1–4 Electric Circuits

series circuit
parallel circuit
fuse
circuit breaker

### 1–5 Electric Power

power

OBSERVATIONS

1. No.
2. Yes.
3. Yes.

ANALYSIS AND CONCLUSIONS

1. No. Yes.
2. To allow the coins to touch the acidic lemon juice; to remove any grease or unwanted chemicals coating the coins.
3. Two different metals and an electrolyte. The lemon juice in this investigation serves as the electrolyte.
4. The needle on the compass is magnetic and will be attracted to the magnetic field set up when the electric current is produced. Thus, the needle deflection shows whether or not an electric current has been produced.
5. There would not be two different metals, and no current would be produced.

GOING FURTHER: ENRICHMENT

**Part 1**

Make a voltmeter available to advanced students and allow them to repeat the investigation, using it in place of the compass, and connecting it in parallel. In this way they will be able to obtain quantitative information on the potential differences involved. You may also wish to provide them with an ammeter to be connected in series. This device will provide them with information on current magnitude and direction. The lemon setup should produce a current of about 0.5 volts.

**Part 2**

Ask students to consider what may be happening on the chemical level during the investigation. Ask them also to consider how the quantitative data that are obtained might change if the data were collected over an extended period of time.

# Chapter Review

## ALTERNATIVE ASSESSMENT

The *Prentice Hall Science* program includes a variety of testing components and methodologies. Aside from the Chapter Review questions, you may opt to use the Chapter Test or the Computer Test Bank Test in your *Test Book* for assessment of important facts and concepts. In addition, Performance-Based Tests are included in your *Test Book*. These Performance-Based Tests are designed to test science process skills, rather than factual content recall. Since they are not content dependent, Performance-Based Tests can be distributed after students complete a chapter or after they complete the entire textbook.

## CONTENT REVIEW

### Multiple Choice

1. c
2. d
3. b
4. b
5. a
6. d
7. d

### True or False

1. T
2. F, gains
3. T
4. T
5. T
6. F, thermocouple
7. F, fuse
8. F, closed
9. T

### Concept Mapping

Row 1: is a property of particles in
Row 2: Electric field
Row 3: Protons, Neutrons, Force
Row 4: Charges are different

# Chapter Review

## Content Review

### Multiple Choice

*Choose the letter of the answer that best completes each statement.*

1. An atomic particle that carries a negative electric charge is called a(n)
   a. neutron. c. electron.
   b. positron. d. proton.
2. Between which particles would an electric force of attraction occur?
   a. proton-proton
   b. electron-electron
   c. neutron-neutron
   d. electron-proton
3. Electricity cannot flow through which of the following?
   a. series circuit c. parallel circuit
   b. open circuit d. closed circuit
4. Electric power is measured in
   a. ohms. c. electron-hours.
   b. watts. d. volts.
5. The three methods of giving an electric charge to an object are conduction, induction, and
   a. friction. c. direct current.
   b. resistance. d. alternating current.
6. Electricity resulting from a buildup of electric charges is
   a. alternating current.
   b. magnetism.
   c. electromagnetism.
   d. static electricity.
7. When electrons move back and forth, reversing their direction regularly, the current is called
   a. direct current. c. electric charge.
   b. series current. d. alternating current.

### True or False

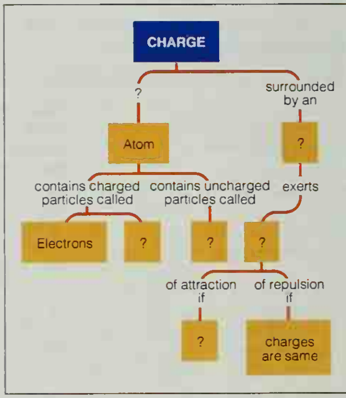
*If the statement is true, write "true." If it is false, change the underlined word or words to make the statement true.*

1. The number of electrons in a neutral atom equals the number of protons.
2. A neutral object develops a negative charge when it loses electrons.
3. An instrument that detects charge is a(n) electroscope.
4. Materials that do not allow electrons to flow freely are called insulators.
5. Rubber is a relatively poor conductor of electricity.
6. A photocell generates electricity as a result of temperature differences.
7. Once a circuit breaker burns out, it must be replaced.
8. An electric circuit provides a complete open path for an electric current.
9. Electric power is the rate at which work is done.



### Concept Mapping

*Complete the following concept map for Section 1–1. Refer to pages P6–P7 to construct a concept map for the entire chapter.*




## CONCEPT MASTERY

1. Atoms are made of smaller particles, including protons, neutrons, and electrons. Protons have a positive charge, and electrons have a negative charge.
2. The first is a repelling force; the second is an attracting force.
3. Conduction (direct contact); friction (rubbing to separate charges); induction (approach of a charged object near a neutral object).
4. An electrochemical cell consists of two different electrodes and an electrolyte. Chemical reactions in the electrolyte release electric charges that create opposite charges on the electrodes. Thus, charge flows between the terminals to which the electrodes are connected. A battery is made of several electrochemical cells.
5. Insulator: does not conduct an electric current or does not allow electrons

## Concept Mastery

*Discuss each of the following in a brief paragraph.*

1. Describe the structure of an atom. How are atoms related to electric charge?
2. How does the force exerted by a proton on a proton compare with the force exerted by a proton on an electron at the same distance?
3. Describe the three ways in which an object can become charged.
4. Describe how a simple electrochemical cell operates? How are electrochemical cells related to batteries?
5. Compare an insulator and a conductor. How might each be used?
6. Describe two ways in which the resistance of a wire can be increased.
7. What is a circuit? A short circuit?
8. Explain why a tiny 1.5-V cell can operate a calculator for a year, while a much larger 1.5-V cell burns out in a few hours in a toy robot.
9. Discuss three safety rules to follow while using electricity.

## Critical Thinking and Problem Solving

*Use the skills you have developed in this chapter to answer each of the following.*

1. **Making calculations** A light bulb operates at 60 volts and 2 amps.
   a. What is the power of the light bulb?
   b. How much energy does the light bulb need in order to operate for 8 hours?
   c. What is the cost of operating the bulb for 8 hours at a rate of $0.07 per kilowatt-hour?
2. **Identifying relationships** Identify each of the following statements as being a characteristic of (a) a series circuit, (b) a parallel circuit, (c) both a series and a parallel circuit:
   a. $I = V/R$
   b. The total resistance in the circuit is the sum of the individual resistances.
   c. The total current in the circuit is the sum of the current in each resistance.
   d. The current in each part of the circuit is the same.
   e. A break in any part of the circuit causes the current to stop.
3. **Applying concepts** Explain why the third prong from a grounded plug should not be removed to make the plug fit a two-prong outlet.
4. **Making inferences** Electric current can be said to take the path of least resistance. With this in mind, explain why a bird can perch with both feet on a power line and not be injured?

5. **Using the writing process** Imagine that from your window you can see the farm that belongs to your neighbors, whom you have never met. You rarely notice the neighbors, except when it rains. During rainstorms, they protect themselves with huge umbrellas as they walk out to check the crops. Write them a friendly but direct letter explaining why it is dangerous for them to use umbrellas during thunderstorms.



o flow; conductor: allows electrons to flow easily.
A conductor is used when you want an electric current to flow, such as in an electric wire. Insulators are most often used for safety purposes to prevent the flow of electrons.
6. The resistance of a wire depends on the material used, thickness, length, and temperature. Resistance can be increased by using a less conductive material, decreasing the thickness of a wire, increasing the length of a wire, or changing the temperature.
7. A circuit is a complete path through which charge can flow. A short circuit is an accidental connection that allows current to take a less resistant path around a circuit.
8. The robot uses the energy more quickly than the calculator does.
9. Answers will vary but should reflect the basic safety rules discussed in the chapter.

### CRITICAL THINKING AND PROBLEM SOLVING

**1a.** 120 watts, **b.** 0.96 kilowatt-hours, **c.** 6.7 cents.
**2a.** both, **b.** series, **c.** parallel, **d.** series, **e.** series.
**3.** Removing the prong would defeat the safety function of the grounding plug.
**4.** The bird is not grounded.
**5.** Check student letters for scientific accuracy. Letters should explain that the umbrellas may act as lightning rods.

### KEEPING A PORTFOLIO

You might want to assign some of the Concept Mastery and Critical Thinking and Problem Solving questions as homework and have students include their responses to unassigned questions in their portfolio. Students should be encouraged to include both the question and the answer in their portfolio.

### ISSUES IN SCIENCE

The following issues can be used as springboards for discussion or given as writing assignments.
**1.** Do you think a third basic type of electric charge is possible? If so, how might a particle having such a charge be recognized? (Students may point out that although there is no experimetnal evidence in favor of its existence, such a charge is at least theoretically possible. They may suggest that a particle having such a charge would be attracted to both positive and negative charges because it would be unlike either, and unlike charges attract.)
**2.** The cost per kilowatt-hour of electricity charged by utility companies often decreases as the number of kilowatt-hours used increases. Does this seem fair? What might be an undesirable effect of this practice on energy conservation as related to individual households and companies? (Some students may feel that such discounting for increased use is fair and is analogous to other economic practices in which goods or services are involved. Others may stress the negative effect of not sufficiently discouraging overuse of energy resources by households and companies.)

# Chapter 2 MAGNETISM

| SECTION | LABORATORY INVESTIGATIONS AND DEMONSTRATIONS |
|---|---|
| **2–1 The Nature of Magnets**<br>pages P46–P52 | **Student Edition**<br>Plotting Magnetic Fields, p. P60<br>**Laboratory Manual**<br>Properties of Magnets and Magnetic Fields<br>**Teacher Edition**<br>Observing Magnetic Properties, p. 44d |
| **2–2 The Earth As a Magnet**<br>pages P52–P55 | **Teacher Edition**<br>Magnetic Force and Distance, p.44d |
| **2–3 Magnetism in Action**<br>pages P56–P59 | |
| **Chapter Review**<br>pages P60–P63 | |

*All materials in the Chapter Planning Guide Grid are available as part of the Prentice Hall Science Learning System.

## OUTSIDE TEACHER RESOURCES

### Books

Ardley, Neil. *Exploring Magnetism*, Watts.

Chikazumi, Sushin, and Stanley H. Charap. *Physics of Magnetism*, Krieger.

Kalvius, G. M., and R. S. Tebbel. *Experimental Magnetism*, vol. 1, Wiley.

McCraig, M. *Permanent Magnets in Theory and Practice*, Halstead.

Vogt, Gregory. *Exploring Magnetism*, Watts.

### Audiovisuals

*Electricity and Magnetism*, filmstrip, Encyclopaedia Britannica Education

*Magnetic, Electric, and Gravitational Fields*, 16-mm film or video, Encyclopaedia Britannica Education

*Magnets*, filmstrip with cassette, LA

*Magnets, Magnetism, and Electricity*, 16-mm film, CRM/McGraw-Hill

| OTHER ACTIVITIES | MULTIMEDIA |
|---|---|
| **Activity Book**<br>Chapter Discovery: Magnetism and Materials<br>ACTIVITY: Magnets<br>ACTIVITY: Magnetic Fields<br>ACTIVITY: Magnetic Transparency<br>ACTIVITY: Magnetic Shielding<br>**Student Edition**<br>Find Out by Doing: Magnetic Forces, p. P46<br>Find Out by Doing: Mapping Lines of Magnetic Force, p. P48<br>Find Out by Doing: Paper Clip Construction, p. P49<br>Find Out by Doing: Magnetic Domains, p. P50<br>Find Out by Writing: Where It All Began, p. P51<br>**Review and Reinforcement Guide**<br>Section 2–1 | **English/Spanish Audiotapes**<br>Section 2–1 |
| **Activity Book**<br>ACTIVITY: Van Allen Radiation Belts<br>**Student Edition**<br>Find Out by Doing: Cork-and-Needle Compass, p. P55<br>**Review and Reinforcement Guide**<br>Section 2–2 | **English/Spanish Audiotapes**<br>Section 2–2 |
| **Student Edition**<br>Find Out by Reading: A Lonely Voyage, p. P58<br>**Review and Reinforcement Guide**<br>Section 2–3 | **English/Spanish Audiotapes**<br>Section 2–3 |
| **Test Book**<br>Chapter Test<br>Performance-Based Test | **Test Book**<br>Computer Test Bank Test |

## CHAPTER OVERVIEW

The ancient Greeks discovered magnetite, a naturally occurring mineral. The magnetism it exhibits is a force of attraction or repulsion due to the electron arrangement in the mineral. Magnets have a north pole and a south pole, where the magnetic forces are usually strongest. Like poles repel each other, and unlike poles attract each other. The region in which such magnetic forces act is called the magnetic field, which is represented by magnetic lines of force.

Natural magnets such as lodestone are found in nature. The most commonly used magnets are made by stroking a magnetic substance with the poles of a permanent magnet. A permanent magnet is one that is difficult to magnetize but retains its magnetism for a long time. A temporary magnet is one that is easy to magnetize but loses its magnetism quickly. A substance becomes magnetized when all its domains align in the same direction. The region in which the magnetic fields of individual atoms are grouped together is called the magnetic domain.

Earth has magnetic properties. Its magnetic field is strongest at its magnetic poles, which are not located at the geographic poles. A permanent record of Earth's magnetic history is found in the magnetic stripes of molten rocks. Compasses point to the magnetic poles of Earth because their needles are magnetized. Like Earth, the planets Jupiter and Saturn as well as the sun have strong magnetic fields.

Earth is surrounded by a strong magnetic field known as the magnetosphere. The Van Allen radiation belts in the magnetosphere trap charged particles, preventing them from reaching Earth's surface. When charged particles come near Earth's surface, they collide with particles in the atmosphere, causing the aurora.

## 2–1 THE NATURE OF MAGNETS

### THEMATIC FOCUS

The purpose of this section is to introduce students to the concept of magnetism. Students first identify characteristics of magnets including the regions of strongest magnetic force, the north and south poles. Like poles repel each other, and unlike poles attract each other. The area over which a magnetic force is exerted is the magnetic field. The atomic structure of materials are responsible for the properties of magnetism, and the region in which the magnetic fields of individual atoms are grouped together is called the magnetic domain. Materials become magnetic when their domains align with one another. Once students are familiar with the properties of magnets, they define magnetism.

The themes that can be focused on in this section are systems and interactions, unity and diversity, stability, and scale and structure.

***Systems and interactions:** Every magnet has a north and a south pole. Like magnetic poles repel each other, and unlike magnetic poles attract each other. If two magnets are placed near each other, the magnetic field of each one will be affected by the other.

**Unity and diversity:** The magnetic forces exerted by any magnet are strongest at the poles. One pole, however, exerts an attractive force, whereas the other pole exerts a repulsive force. All magnets, regardless of their size or shape, have a pair of poles.

***Stability:** The magnetic lines of a force of a magnet move in a complete circle from the north pole to the south pole. The magnetic lines of force trace the magnetic field of a magnet.

***Scale and structure:** Every magnet, regardless of its size or strength, has two ends, called the north and south poles, where the magnetic effects are usually strongest. In magnets, the poles always come in pairs that cannot be separated.

### PERFORMANCE OBJECTIVES 2–1

**1. Define magnetism.**
**2. Describe the property of magnetic poles.**
**3. Explain the appearance and use of magnetic lines of force in relationship to magnetic fields.**
**4. Identify the magnetic domain.**
**5. Compare and contrast permanent and temporary magnets.**

### SCIENCE TERMS 2–1

**magnetism p. P46**
**pole p. P46**
**magnetic field p. P48**
**magnetic domain p. P50**

## 2–2 THE EARTH AS A MAGNET

### THEMATIC FOCUS

The purpose of this section is to introduce students to the magnetic properties of the Earth. The Earth is like a large bar magnet with magnetic north and south poles. The magnetic history of Earth can be traced through the magnetic stripes in molten rocks. The patterns of the stripes show that Earth's magnetic poles have reversed themselves many times throughout Earth's history. Because of its magnetized needle, a compass can be used to identify the north pole. The needle points to the magnetic pole, which does not coincide with the geographic pole. The sun has a strong magnetic field, as do the planets Jupiter and Saturn. Sunspots are very strong fields of magnetism. They always appear in pairs, with one sunspot acting as the north pole and one acting as the south pole.

The themes that can be focused on in this section are evolution, scale and structure, and patterns of change.

**Evolution:** Changes in Earth's magnetic field over time are recorded in the patterns of magnetic rocks. These rocks provide evidence that Earth has reversed its poles many times throughout its history.

***Scale and structure:** Objects as large as the Earth and the sun produce magnetic fields evident throughout the solar system. Yet the source of magnetism is in the atom—the building block of matter.

**Patterns of change:** The patterns of magnetic stripes in molten rocks are fixed at the time that the rocks solidify. The patterns in rocks of different ages are different, indicating that the Earth's magnetic poles have reversed themselves over time. The number of sunspots varies in 11-year cycles. The cycle is believed to be related to variations in the sun's magnetic field. Every 11 years, the sun's north and south poles reverse themselves.

### PERFORMANCE OBJECTIVES 2-2

**1. Describe the magnetic poles and magnetic field of Earth.**
**2. Explain the behavior of compasses.**
**3. Distinguish between geographic and magnetic poles.**
**4. Identify sources of magnetism in the solar system.**

## 2-3 MAGNETISM IN ACTION

### THEMATIC FOCUS

The purpose of this section is to introduce students to the impact of magnetism on charged particles. The Earth is surrounded by the region in which the magnetic field of Earth is found known as the magnetosphere. The region traps charged particles, preventing them from reaching Earth's surface. The Van Allen radiation belts are parts of the magnetosphere in which most charged particles are trapped. The aurora is a phenomenon that results when charged particles collide with atmospheric particles near Earth's surface. Charged particles spiraling in magnetic fields release radiation. Radio waves, a type of radiation, are studied by astronomers to learn about objects in space. By using magnetic fields, scientists may be able to solve energy needs through nuclear fusion.

The themes that can be focused on in this section are energy, systems and interactions, patterns of change, and unity and diversity.

***Energy:** Energy is required to overcome the magnetic forces of attraction and repulsion. Energy is released in the form of light when charged particles move near the Earth's surface close to the poles and collide with atmospheric particles.

***Systems and interactions:** A charged particle moving in the same direction as a magnetic field has no force exerted on it. A charged particle moving at an angle to a magnetic field has a force acting on it that causes it to spiral around the magnetic-field lines. The charged particle spirals from pole to pole within the magnetic field.

**Patterns of change:** The motions of a charged particle will be altered by the magnetic forces exerted in a magnetic field. Charged particles near Earth's surface collide with atmospheric particles and cause the aurora.

**Unity and diversity:** The aurora borealis and aurora australis are identical phenomena. They are produced, however, by interactions of particles at opposite poles. Aurora borealis occurs near the North Pole and aurora australis occurs near the South Pole.

### PERFORMANCE OBJECTIVES 2-3

1. Describe the magnetosphere.
2. Explain the phenomenon of aurora.
3. Identify how magnetism relates to astronomy and the development of nuclear fusion.

### SCIENCE TERMS 2-3

**magnetosphere p. P57**
**aurora p. P57**

### Discovery Learning

### TEACHER DEMONSTRATIONS MODELING

#### Observing Magnetic Properties

Obtain a sample of the naturally magnetic magnetite (lodestone). The sample should be large enough to be easily visible to the class and should have an elongated (rather than a spherical) shape. Do not tell students the name of the mineral.

Use a string to hang the sample from a support. Ask students to observe the magnetite's orientation. Carefully rotate the support 90 degrees. But before doing so, ask:

- **What will happen if the support is turned? Why?** (The mineral will keep its orientation. It is naturally magnetic, and its north pole points toward the Earth's magnetic north pole.)

Use a compass to reveal the sample's magnetic orientation. Also use the sample to pick up paper clips or small nails. If more than one magnetite mineral is available, allow students to examine the mineral and use it to pick up various items.

- **Why does the magnetite pick up the paper clips?** (It is magnetized, and the paper clips become slightly magnetized.)
- **Will the magnetite pick up paper? Why?** (No. Paper does not have magnetic properties and cannot be magnetized by the magnetite.)

#### Magnetic Force and Distance

Explore the dependency of magnetic force on distance. Ask students to write a hypothesis explaining how an object's distance from a magnet may affect the attractive force of the magnet. Then perform the demonstration. Make use of a pole of a strong magnet in this demonstration. Hang a small iron object on a spring balance designed to measure force, and first measure the force of gravity, in newtons, acting on the object when it is far from the magnet. Subtract this value from subsequent readings. Record the values obtained on a data chart on the chalkboard. Hold the object (suspended from the spring balance) at various short distances above the magnetic pole and record the resulting force on the object. Demonstrate that the force decreases rapidly with distance. Have students check their hypotheses. Did the demonstration support their hypotheses? (Answers will vary.)

## CHAPTER 2
# *Magnetism*

### INTEGRATING SCIENCE

This physical science chapter provides you with numerous opportunities to integrate other areas of science, as well as other disciplines, into your curriculum. Blue numbered annotations on the student page and integration notes on the teacher wraparound pages alert you to areas of possible integration.

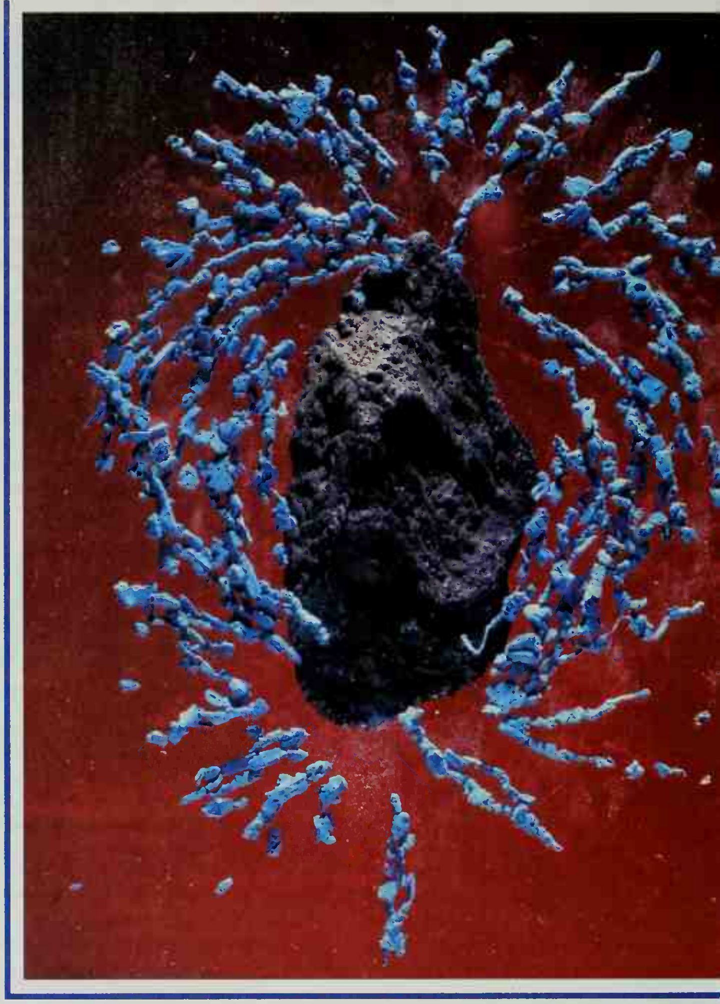
In this chapter you can integrate earth science and cosmology (p. 47), physical science and scientific method (p. 48), language arts (pp. 49, 51), physical science and heat (p. 51), earth science and geology (pp. 52, 53), earth science and astronomy (pp. 54, 56), physical science and light (p. 57), earth science and radio telescopes (p. 58), physical science and fusion (p. 58), and earth science and continental drift (p. 59).

### SCIENCE, TECHNOLOGY, AND SOCIETY/COOPERATIVE LEARNING

Using technology developed by American scientists, Japanese and German companies are waiting for advancements in superconducting magnets to put the first magnetic levitation trains into production. These trains float above the tracks at speeds approaching 480 kilometers per hour.

Magnetic levitation trains (maglev) can work on magnetic repulsion or magnetic attraction. One type of maglev uses superconducting magnets to propel the train forward and keep the train 6 to 8 centimeters above the guideways. The superconducting magnets in the train and the guideways repel each other to maintain the separation and prevent friction from slowing the train's speed. Another type of maglev uses the principle of magnetic attraction to propel the train down the tracks at high rates of speed. Magnets in the guideways and on the train are of opposite polarity, and the attraction force pulls the train forward down the "tracks."

The gridlock overtaking United States highways and airports and our rapidly deteriorating infrastructure makes the United States a prime location for maglev trains. Maglev trains also have very



## INTRODUCING CHAPTER 2

### DISCOVERY LEARNING

▶ *Activity Book*

Begin teaching the chapter by using the Chapter 2 Discovery Activity from the *Activity Book*. Using this activity, students will discover whether or not magnetism can pass through various materials.

### USING THE TEXTBOOK

Have students observe the photograph on page P44 and read the caption on page P45.

- **What does it mean to say that this rock is a natural magnet?** (Accept all logical answers. Encourage students to tell what they know about magnets and how they work.)
- **Have you ever seen a rock that is a magnet?** (Accept all answers. Ask stu-

# Magnetism

## Guide for Reading

*After you read the following sections, you will be able to*

**2–1 The Nature of Magnets**

- Describe magnetism and the behavior of magnetic poles.
- Relate magnetic fields and magnetic field lines of force.
- Explain magnetism in terms of magnetic domains.

**2–2 The Earth As a Magnet**

- Describe the Earth's magnetic properties.
- Explain how a compass works.
- Identify other sources of magnetism in the solar system.

**2–3 Magnetism in Action**

- Explain what happens to a charged particle in a magnetic field.

More than 2000 years ago, the Greeks living in a part of Turkey known as Magnesia discovered an unusual rock. The rock attracted materials that contained iron. Because the rock was found in Magnesia, the Greeks named it magnetite. As the Greeks experimented with their new discovery, they observed another interesting thing about this peculiar rock. If they allowed it to swing freely from a string, the same part of the rock would always face in the same direction. That direction was toward a certain northern star, called the leading star, or lodestar. Because of this property, magnetite also became known as lodestone.

The Greeks did not know it then, but they were observing a property of matter called magnetism. In this chapter you will discover what magnetism is, the properties that make a substance magnetic, and the significance of magnetism in your life.

### Journal *Activity*

***You and Your World*** You probably use several magnets in the course of a day. In your journal, describe some of the magnets you encounter and how they are used. Also suggest other uses for magnets.

*Magnetite, or lodestone, is a natural magnet that exhibits such properties as attracting iron filings.*



low energy requirements and have only minimal impact on the environment. Once maglev technology has been perfected and placed in production, the real challenge will be to get Americans out of their individual cars and onto this efficient, high-speed form of transportation.

**Cooperative learning:** Using preassigned lab groups or randomly selected teams, have groups complete one of the following assignments:

- Your group has been selected by the Public Transportation Department of the city of Los Angeles to design an advertising campaign that will increase the number of people who ride on the new maglev transit system. Encourage groups to first consider reasons that people choose not to use public transportation and then eliminate these objections with their ads. You may want to randomly assign a specific type of media to each group or have them prepare ads that would be appropriate for different types of media.
- Maglev technology holds a great deal of promise, but American scientists are concerned that government support of maglev research and money to fund maglev construction projects may be lacking. What role should the U.S. government take in these areas? Have groups discuss this question and suggest possible positions for the federal government.

See Cooperative Learning in the *Teacher's Desk Reference.*

## JOURNAL ACTIVITY

You may want to use the Journal Activity as the basis of a class discussion. As students discuss their daily experiences with magnets, ask them to identify the function of the magnet. Encourage students to explore all parts of their environment for uses of magnets. Students should be instructed to keep their Journal Activity in their portfolio.

dents who have seen such a rock to describe it.)

Have students read the chapter introduction on page P45. Explain that it is not really known who first found magnetite or when it was found. A rock with its properties was mentioned in Greek texts in 800 BC. But it is possible that the Chinese knew about magnetite as early as 2600 BC.

- **What would be useful about a rock that always points north?** (Accept all logical answers. Lead students to realize that the rock could be used as a navigational instrument.)
- **What is the name of a direction-finding instrument that uses magnetism?** (A compass.)

Explain that the compass is the oldest practical use of magnetism but that the actual origin of the compass is unknown. The existence of the lodestone made the compass possible.

# 2-1 The Nature of Magnets

## MULTICULTURAL OPPORTUNITY 2-1

Have your students investigate the life and work of Kotaro Honda (1870–1954). Honda discovered that the addition of cobalt to tungsten steel formed an alloy with powerful magnetic properties. This led to the discovery of alnico, a magnetic alloy that is stronger, more corrosive resistant, more immune to temperature and vibration change, and cheaper than steel magnets.

## ESL STRATEGY 2-1

When discussing magnetism, point out the textbook's description of it as a "strange phenomenon." Make sure students know the singular and plural forms: *phenomenon, phenomena.* Give other examples of phenomena, such as lightning and auroras. Can students think of other examples?

The Intruder: Have students circle the term that does not belong in the group and then write definitions for the uncircled words.

- magnetic lines of force, magnetic tape, magnetic poles, magnetic fields

**Guide for Reading**

*Focus on these questions as you read.*

- *What are the characteristics of a magnetic field?*
- *How is magnetism related to the atomic structure of a material?*

# 2–1 The Nature of Magnets

Have you ever been fascinated by the seemingly mysterious force you feel when you try to push two magnets together or pull them apart? This strange phenomenon is known as **magnetism.** You may not realize it, but magnets play an extremely important role in your world. Do you use a magnet to hold notes on your refrigerator or locker door? Do you play video- and audiotapes? Perhaps you have used the magnet on an electric can opener. Did you know that a magnet keeps the door of your freezer sealed tight? See, you do take advantage of the properties of magnets.

**FIND OUT BY DOING**

*Magnetic Forces*

**1.** Take two bar magnets of the same size and hold one in each hand.

**2.** Experiment with the magnets by bringing different combinations of poles together. What do you feel in your hands?

■ Explain your observations in terms of magnetic forces.

## Magnetic Poles

All magnets exhibit certain characteristics. Any magnet, no matter what its shape, has two ends where its magnetic effects are strongest. These regions are referred to as the **poles** of the magnet. One pole is labeled the north pole and the other the south pole. Magnets come in different shapes and sizes. The simplest kind of magnet is a straight bar of iron. Another common magnet is in the shape of a horseshoe. In either case, the poles are at each end. Figure 2–1 shows a variety of common magnets.


**Figure 2–1** *Modern magnets come in a variety of sizes and shapes, including bar magnets, horseshoe magnets, and disc magnets.*

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## TEACHING STRATEGY 2-1

### FOCUS/MOTIVATION

Bring the N-pole of a bar magnet near the N-pole of a freely suspended magnet.

- **What do you observe?** (The suspended magnet moves away from the other magnet.)

Repeat bringing the S-pole of the bar magnet near the S-pole of the suspended magnet. Now place the S-pole of the bar magnet near the N-pole of the suspended magnet.

- **What do you observe?** (The suspended magnet moves toward the other magnet.)

Ask students to state their observations as a rule. The statement should be "Like magnetic poles repel, and unlike magnetic poles attract." Point out that this rule describes the behavior of magnetic poles.

Make available to students a number of small horseshoe magnets with labeled north and south poles, strings, and metal paper clips. Allow students to use the materials to investigate the magnetic properties of attraction and repulsion and alignment of the magnets in north-south directions when allowed to swing freely. Ask students to consider what may account for the properties of magnets.

### CONTENT DEVELOPMENT

As the various properties of magnets are introduced and explored, list the properties on the chalkboard. Ask students the following:

- **Do the attraction and repulsion properties of magnets remind you of properties you studied earlier?** (Objects with like and unlike electric charges have similar properties of attraction and repulsion.)
- **Is it possible that magnets are simply**

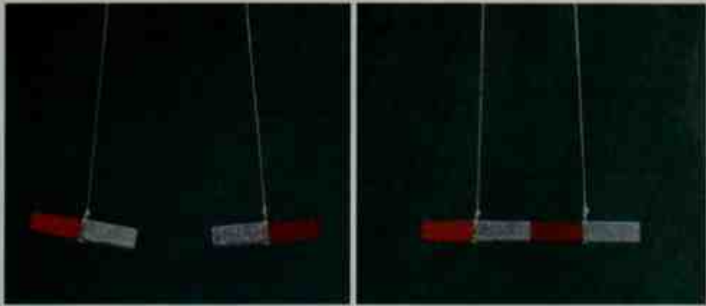
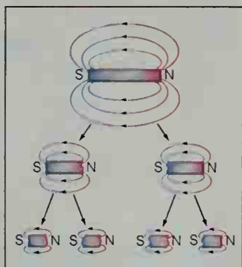


**Figure 2-2** *Two bar magnets suspended by strings are free to move. What force is occurring between the magnets in each photograph? Why?* 1

When two magnets are brought near each other, they exert a force on each other. Magnetic forces, like electric forces, involve attractions and repulsions. If the two north poles are brought close together, they will repel each other. Two south poles do the same thing. However, if the north pole of one magnet is brought near the south pole of another magnet, the poles will attract each other. The rule for magnetic poles is: Like poles repel each other and unlike poles attract each other. How does this rule compare with the rule that describes the behavior of electric charges? 2

Magnetic poles always appear in pairs—a north pole and a south pole. For many years, physicists have tried to isolate a single magnetic pole. You might think that the most logical approach to separating poles would be to cut a magnet in half. Logical, yes; correct, no. If a magnet is cut in half, two smaller magnets each with a north pole and a south pole are produced. This procedure can be repeated again and again, but a complete magnet is always produced. Theories predict that it should be possible to find a single magnetic pole (monopole), but experimental evidence does not agree. A number of scientists are actively pursuing such a discovery because magnetic monopoles are believed to have played an important role in the early history of the universe.

**Figure 2-3** *No matter how many times a magnet is cut in half, each piece retains its magnetic properties. How are magnetic poles different from electric charges?* 3






## ANNOTATION KEY

### Answers

1 Left: Repulsion—like poles; right: Attraction—unlike poles. (Interpreting photographs)

2 Same: Like charges repel each other, and unlike charges attract each other. (Making comparisons)

3 Magnetic poles always appear in pairs—a north pole and a south pole. This is not true of electric charges.

### Integration

1 Earth Science: Cosmology. See *Exploring the Universe,* Chapter 1.

## FIND OUT BY DOING

### MAGNETIC FORCES

**Discovery Learning**

***Skills: Manipulative, observing, comparing, hypothesizing***

***Materials: 2 bar magnets***

This activity will enable students to actually feel the magnetic forces caused by bar magnets. Students will be able to feel the force of attraction when unlike poles are brought together, as well as the force of repulsion when like poles are brought together.

**electrically charged objects, with a positive charge at one end and a negative charge at the other? How might you investigate this possibility?** (Some students may incorrectly conclude that magnetism and electric charge are identical rather than simply related, as they turn out to be. Students may suggest testing magnets to see whether they attract electrically charged objects, such as rubber balloons or glass rods. Actually carry out such tests to show that there is no such attraction and that magnets do not have net electric charges.)

**• • • • Integration • • • •**

Use the discussion on the possible existence of a magnetic monopole to integrate concepts of cosmology into your lesson.

### ENRICHMENT

Advanced students may wish to do library research to obtain more information on the discovery of magnetism and the properties of magnets. Have them report their findings to the class.

### REINFORCEMENT/RETEACHING

▶ *Activity Book*

Students who need further practice with the concept of magnets and their properties should complete the chapter activity called Magnets.

## FIND OUT BY DOING

### MAPPING LINES OF MAGNETIC FORCE

**Discovery Learning**

***Skills: Manipulative, observing, diagramming, relating***

***Materials: horseshoe magnet, iron filings, thin piece of cardboard, pencil***

In this activity students observe the lines of force produced by a horseshoe magnet through the use of iron filings. Check students' drawings for accuracy. Students should note from the pattern that the poles of the horseshoe magnet are at each end.

## FIND OUT BY DOING

*Mapping Lines of Magnetic Force*

For this activity you need iron filings, a horseshoe magnet, a thin piece of cardboard, a pencil, and a sheet of paper.

**1.** Place the horseshoe magnet on a flat surface. Place the cardboard on top of it. Be sure the cardboard covers the entire magnet.

**2.** Sprinkle iron filings over the cardboard. Make a drawing of the pattern you see.

- Explain why this particular pattern is formed.
- What does the pattern tell you about the location of the poles of a horseshoe magnet?

You may think that science has all the answers and that everything has been discovered that can be discovered. But the quest for monopoles illustrates that scientific knowledge is continually developing and changing. It is often the case that a scientific discovery creates a whole new collection of questions to be answered—perhaps by inquisitive minds like yours.

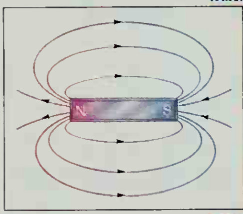
## Magnetic Fields

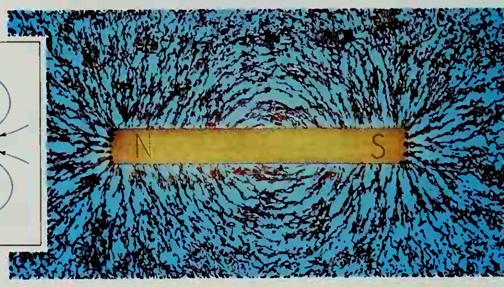
Although magnetic forces are strongest at the poles of a magnet, they are not limited to the poles alone. Magnetic forces are felt around the rest of the magnet as well. The region in which the magnetic forces can act is called a **magnetic field.**

It may help you to think of a magnetic field as an area mapped out by magnetic lines of force. Magnetic lines of force define the magnetic field of an object. Like electric field lines, magnetic field lines can be drawn to show the path of the field. But unlike electric fields, which start and end at charges, magnetic fields neither start nor end. They go around in complete loops from the north pole to the south pole of a magnet. **A magnetic field, represented by lines of force extending from one pole of a magnet to the other, is an area over which the magnetic force is exerted.**

Magnetic lines of force can be easily demonstrated by sprinkling iron filings on a piece of cardboard placed on top of a magnet. See Figure 2–4. Where are the lines of force always the most numerous and closest together? (1)

**Figure 2–4** *You can see the magnetic lines of force mapped out by the iron filings placed on a glass sheet above a magnet. The diagram illustrates these lines of force. Where are the lines strongest?* (2)






## 2–1 (continued)

### GUIDED PRACTICE

▶ *Laboratory Manual*

**Skills Development**

***Skills: Making observations, drawing conclusions***

Have students complete the Laboratory Investigation called Properties of Magnets and Magnetic Fields. They will use simple bar magnets and iron filings to explore properties of magnets and to observe a magnetic field.

### CONTENT DEVELOPMENT

The strengths of the magnetic fields of different magnets can differ considerably. The magnetic field can thus be thought of as a quantity that can have different magnitudes. It is also a directional quantity. Because both magnitude and direction are involved, it is therefore a vector quantity. Magnetic field, or more precisely, the magnetic induction of a field, is symbolized by the letter B with an arrow written above it to indicate its vector nature: $\vec{B}$. The units in which B is measured are the tesla and the gauss (1 tesla = $10^4$ gauss).

**• • • • Integration • • • •**

Use the discussion of the questions raised by the study of magnetism to integrate concepts of the scientific method into your lesson.

### GUIDED PRACTICE

**Skills Development**

***Skills: Making observations, identifying relationships, performing an experiment***

Provide students with two bar magnets, sheets of paper, and iron filings. Have students use these materials to observe magnetic lines of force for one magnet alone, and for N–S, N–N, and S–S interactions between magnets. They should make sketches of what they observe.

### INDEPENDENT PRACTICE

▶ *Activity Book*

Students can gain a better understanding of magnetic fields by completing the chapter activity Magnetic Fields, in which they observe magnetic fields for a single

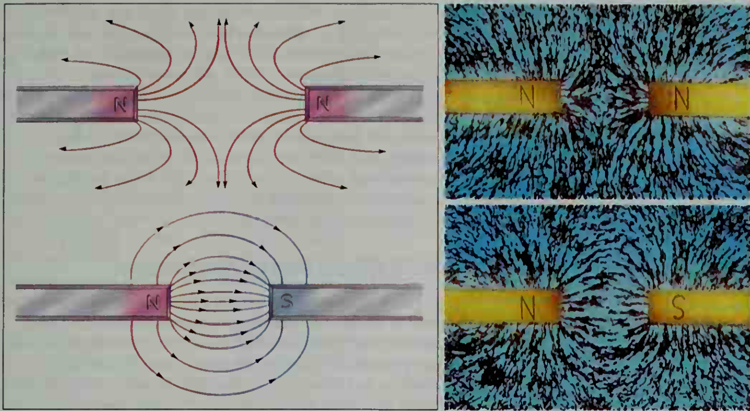



**Figure 2–5** *What do the lines of force around these magnets tell you about the interaction of like and unlike magnetic poles?* 3

Figure 2–5 shows the lines of force that exist between like and unlike poles of two bar magnets. The pattern of iron filings shows that like poles repel each other and unlike poles attract each other.

## Magnetic Materials

If you bring a magnet near a piece of wood, glass, aluminum, or plastic, what happens? You are right if you say nothing. There is no action between the magnet and any of these materials. In addition, none of these materials can be magnetized. Yet materials such as iron, steel, nickel, and cobalt react readily to a magnet. And all these materials can be magnetized. Why are some materials magnetic while others are not?

The most highly magnetic materials are called ferromagnetic materials. The name comes from the Latin name for iron, *ferrum*. Ferromagnetic materials are strongly attracted to magnets and can be made into magnets as well. For example, if you bring a strong magnet near an iron nail, the magnet will attract the nail. If you then stroke the nail several times in the same direction with the magnet, the nail itself becomes a magnet. The nail will remain magnetized even after the original magnet is removed.

### FIND OUT BY DOING

*Paper Clip Construction*

**1.** How many paper clips can you make stick to the surface of a bar magnet?

- Explain your results.

**2.** How many paper clips can you attach in a single row to a bar magnet?

- Explain your results.
- What would happen if you placed a plastic-coated paper clip in the second position?



### ANNOTATION KEY

Answers

1 Near the poles of the magnet. (Interpreting illustrations)

2 Near the poles of the magnet. (Interpreting illustrations)

3 Like poles attract; unlike poles repel. (Interpreting illustrations)

Integration

1 Physical Science: Scientific Method. See *The Nature of Science*, Chapter 1.

2 Language Arts

### FIND OUT BY DOING

PAPER CLIP CONSTRUCTION

**Discovery Learning**

***Skills: Observing, inferring, relating***

***Materials: bar magnet, metal paper clips, plastic-coated paper clips***

Students will find that the greatest number of paper clips will stick to the poles where the magnetic force is strongest. The exact number of paper clips will vary, depending on the size and strength of the magnet. Students will find that many paper clips will stick even if they do not actually touch the surface of the magnet. This is also demonstrated in the single row of paper clips. In each case, the magnet induces magnetism in the paper clips—each clip becomes a magnet itself.

bar magnet, two bar magnets with opposing poles, and two bar magnets with like poles.

### GUIDED PRACTICE

**Skills Development**

***Skills: Making observations, applying concepts***

At this point have students complete the in-text Laboratory Investigation called Plotting Magnetic Fields. They will draw representations of the magnetic fields of a bar magnet and a horseshoe magnet.

### FOCUS/MOTIVATION

Give each student a small magnet and a few small samples of metal and nonmetal objects such as a paper clip, brass or aluminum key, aluminum foil, brass screw, copper penny or wire, iron nail, thumb tack, piece of Styrofoam, wooden toothpick, and/or other available materials. Have students test the magnetic properties of these materials.

• **What have you observed about magnets?** (The attract metals and do not attract nonmetals. Only the objects of iron and steel are attracted to the magnet. Aluminum, copper, and brass do not seem to stick to the magnet.)

**Integration**

Use the discussion of the derivation of the word *ferromagnetic* to integrate language arts concepts into your science lesson.

## FIND OUT BY DOING

### MAGNETIC DOMAINS

***Skills: Comparing, modeling, hypothesizing***

***Materials: index cards, posterboard***

In this simple activity students are asked to make models of magnetized and unmagnetized substances. Check students' models, as well as their written explanations, for accuracy.

## FIND OUT BY DOING

*Magnetic Domains*

**1.** Cut several index cards into small strips to represent magnetic domains. Label each strip with a north pole and a south pole.

**2.** On a sheet of posterboard, arrange the strips to represent an unmagnetized substance.

**3.** On another sheet of posterboard, arrange the strips to represent a magnetized substance.

Provide a written explanation for your model.

Some materials, such as soft iron, are easy to magnetize. But they also lose their magnetism quickly. Magnets made of these materials are called temporary magnets. Other magnets are made of materials that are more difficult to magnetize, but they tend to stay magnetized. Magnets made of thes materials are called permanent magnets. Cobalt, nickel, and iron are materials from which strong permanent magnets can be made. Many permanent magnets are made of a mixture of aluminum, nickel cobalt, and iron called alnico.

## An Explanation of Magnetism

**The magnetic properties of a material depend on its atomic structure.** Scientists believe that the atom itself has magnetic properties. These magnetic properties are due to the motion of the atom's electrons. Groups of atoms join in such a way that their magnetic fields are all arranged in the same direction, or aligned. This means that all the north poles face in one direction and all the south poles face in the other direction. A region in which the magnetic fields of individual atoms are grouped together is called a **magnetic domain.**

You can think of a magnetic domain as a miniature magnet with a north pole and a south pole. All materials are made up of many domains. In unmagnetized material, the domains are arranged randoml (all pointing in different directions). Because the domains exert magnetic forces in different directions, they cancel out. There is no overall magnetic force in the material. In a magnet, however, most o the domains are aligned. See Figure 2–6.

A magnet can be made from an unmagnetized material such as an iron nail by causing the domains to become aligned. When a ferromagnetic material i placed in a strong magnetic field, the poles of the magnet exert a force on the poles of the individual domains. This causes the domains to shift. Either

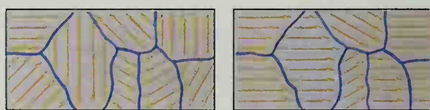



**Figure 2–6** *The sections represent the various domains of a material. The arrows point toward the north pole of each domain. What is the arrangement of the domains in an unmagnetized material? In a magnetized material?* 1



## 2–1 (continued)

### INDEPENDENT PRACTICE

▶ *Activity Book*

Students can learn more about magnetism by completing the chapter activity Magnetic Transparency. They will discover which materials allow magnetic fields to pass through and to what extent the magnetic fields remain unchanged.

### FOCUS/MOTIVATION

Stroke an iron nail repeatedly with a strong magnet. Use the nail to attract a paper clip and support the nail and attached clip so that they are easily visible.

- **What has happened to the nail?** (It has become magnetized.)
- **Why has this happened?** (Answers will vary. The magnetic domains in the nail have lined up in the same direction.)

After a short time, the clip will drop off.

- **Why has this happened?** (The magnetic domains have returned to a random arrangement.)

### CONTENT DEVELOPMENT

Direct students' attention to Figure 2–6. Discuss the diagram in terms of random and aligned magnetic domains, taking care first to explain the concept of such domains as regions in which the magnetic fields of large numbers of atoms are overlapped and, in a sense, grouped together and unified. Use this concept to explain the property of certain materials to be magnetized and the ability of magnets to be cut in two to produce two smaller magnets, each with a north and a south pole.

**• • • • Integration • • • •**

Use the discussion of magnetized and unmagnetized objects to integrate concepts of heat into your lesson.

### ENRICHMENT

▶ *Activity Book*

Students will be intrigued by the chap ter activity Magnetic Shielding. They us a magnet, a paper clip, and string to tes different materials' ability to provid shielding against the effect of a magneti field.

most of the domains rotate (turn) to be in the direction of the field, or the domains already aligned with the field become larger while those in other directions become smaller. In both situations, an overall magnetic force is produced. Thus the material becomes a magnet.

This also explains why a magnet can pick up an unmagnetized object, such as a paper clip. The magnet's field causes a slight alignment of the domains in the paper clip so that the clip becomes a temporary magnet. Its north pole faces the south pole of the permanent magnet. Thus it is attracted to the magnet. When the magnet is removed, the domains return to their random arrangement and the paper clip is no longer magnetized.

Even a permanent magnet can become unmagnetized. For example, if you drop a magnet or strike it too hard, you will jar the domains into randomness. This will cause the magnet to lose some or all of its magnetism. Heating a magnet will also destroy its magnetism. This is because the additional energy (in the form of heat) causes the particles of the material to move faster and more randomly. In fact, every material has a certain temperature above which it cannot be made into a magnet at all.

Now that you have learned more about the nature of magnets, you can better describe the phenomenon of magnetism. **Magnetism is the force of attraction or repulsion of a magnetic material due to the arrangement of its atoms—particularly its electrons.**

**Figure 2–7** *This iron nail attracts metal paper clips. How can an iron nail be turned into a magnet?* 2

## 2–1 Section Review

1. How is a magnetic field related to magnetic poles and lines of force?
2. State the rule that describes the behavior of magnetic poles.
3. What is magnetism?
4. What is a magnetic domain? How are magnetic domains related to magnetism?

**Critical Thinking—*Applying Concepts***

5. From what you know about the origin of magnetism, explain why cutting a magnet in half produces two magnets.

## FIND OUT BY WRITING

*Where It All Began*

The phenomenon of magnetism has been known for many centuries, well before it was actually understood. Various references to this "magical" property can be found in ancient Chinese and Greek mythology. Using reference materials from your library, find out about the discovery and history of lodestones. Write a report describing how lodestone was discovered, what people first thought of it, and how it has come to be understood and used. 2

### ANNOTATION KEY

**Answers**

1 Randomly; they all point in different directions. Most of the domains are aligned in the same direction. (Applying concepts)

2 Stroke the nail with a strong magnet. (Applying facts)

**Integration**

1 Physical Science: Heat. See *Heat Energy*, Chapter 1.

2 Language Arts

### FIND OUT BY WRITING

WHERE IT ALL BEGAN

Students should be sure to include Roman ideas about magnetism, especially the story of the shepherd Magnes. Also have them investigate the contributions of Petrus Peregrinus de Maricourt and William Gilbert. You may wish to have students present their reports to the class and compare their findings. To emphasize how long people have known about magnetism, have students work together to make a time line showing major events in the study of magnetism.

**Integration:** Use the Find Out by Writing feature to integrate language arts skills into your science lesson.

### INDEPENDENT PRACTICE

**Section Review 2-1**

1. A magnetic field, represented by lines of force extending from one pole of a magnet to the other, is an area over which the magnetic force is exerted.
2. Like poles repel each other, and unlike poles attract each other.
3. The force of attraction or repulsion of a magnetic material due to the arrangement of its atoms—particularly its electrons.
4. A region in which the magnetic fields of individual atoms are grouped together; in magnetized material, the magnetic domains are aligned in the same direction, whereas in unmagnetized material, the magnetic domains are arranged randomly.
5. When a magnet is cut in half, its magnetic domains are still aligned in the same direction in each half. Therefore, each half becomes a magnet with a north pole and a south pole.

### REINFORCEMENT/RETEACHING

Monitor students' responses to the Section Review questions. If students appear to have difficulty understanding any of the concepts, review this material with them.

### CLOSURE

▶ *Review and Reinforcement Guide*

At this point have students complete Section 2–1 in the *Review and Reinforcement Guide*.

# *2-2 The Earth As a Magnet*

MULTICULTURAL OPPORTUNITY 2-2

Have your students investigate some of the peoples who live near the North Pole. What is the life like for these cultures that live in cold regions where they experience months of no sunlight?

ESL STRATEGY 2-2

Dictate the questions below. Have students work in small groups. One student reads the question, another student responds, and a third confirms or corrects the answer.

1. What is the scientific term used to explain the difference between a magnetic pole and a geographic pole?
2. In addition to Earth, how do scientists explain magnetism's existence on Jupiter, Saturn, and the sun?

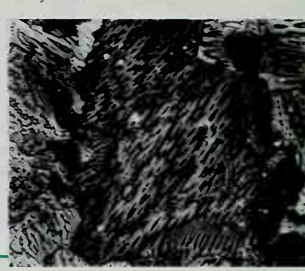
## PROBLEM Solving

### *Mix-Up in the Lab*

You are working in a research laboratory conducting experiments regarding the characteristics of magnets. You have several samples of magnetic materials and several samples of materials that are not magnetic. Unfortunately, you also have a problem. One of your inexperienced laboratory assistants has removed the label identifying one particular sample as magnetic or not magnetic. To make matters worse, you must complete this part of your research before your boss returns.

**Drawing Conclusions**

All you have is this photograph showing the pattern of the magnetic domains of the sample. Is the sample a magnet? Explain how you reached your conclusion. Devise an experiment for your lab assistant to perform to prove your conclusion so that the sample can be correctly labeled.



**Guide for Reading**

*Focus on these questions as you read.*

- *What are the magnetic properties of the Earth?*
- *How does a compass work?*

## 2–2 The Earth As a Magnet

You have read earlier that as the ancient Greeks experimented with magnetite, they discovered that the same part of the rock always pointed in the same direction. Why does one pole of a bar magnet suspended from a string always point north and the other pole always point south? After all, the poles of a magnet were originally labeled simply to describe the directions they faced with respect to the Earth.

The first person to suggest an answer to this question was an English physician named William Gilbert. In 1600, Gilbert proposed the idea that the Earth itself is a magnet. He predicted that the Earth would be found to have magnetic poles.

Gilbert's theory turned out to be correct. Magnetic poles of the Earth were eventually discovered.



## TEACHING STRATEGY 2-2

### FOCUS/MOTIVATION

Draw students' attention to a world globe and ask them what properties would be observable if the Earth were a magnet, as Gilbert correctly proposed. Then actually hold a strong bar magnet more or less parallel to the north-south axis of the globe and ask students to imagine the magnet embedded in the globe.

• **How would free-swinging magnets and compasses behave when placed at different points of the globe?** (They would align themselves in a north-south [relative to the globe] orientation. Some students may then realize that the true magnetic north pole of the Earth must be in the geographic south, in order for the north poles of magnets to point northward. Do not as yet remark on the correctness of this conclusion, which will be taken up shortly.)

### CONTENT DEVELOPMENT

Explain that William Gilbert was physician to Elizabeth I and James I of England. He spent 17 years experimenting with magnetism and wrote his findings in a lengthy treatise. Not only did he propose that the Earth was a huge magnet, he also introduced the term *electric* to describe the force that exists between two objects that are charged by friction. Gilbert also conducted early experiments on electricity. Because of this, he is considered to be the founder of the modern sciences of electricity and magnetism.

#### • • • • Integration • • • •

Use the discussion of Gilbert's proposal to integrate geology concepts into your lesson.

### GUIDED PRACTICE

**Skills Development**

***Skill: Interpreting a diagram***

Direct students' attention to Figure 2-8. First explain that the geographic North and South poles are not the same as the magnetic north and south poles. In

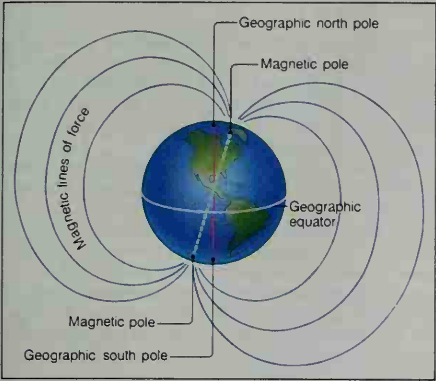



**Figure 2–8** *You can see in this illustration that the magnetic poles are not located exactly at the geographic poles. Does a compass needle, then, point directly north?* 1

Today, scientists know that the Earth behaves as if it has a huge bar magnet buried deep within it. **The Earth exerts magnetic forces and is surrounded by a magnetic field that is strongest near the north and the south magnetic poles.** The actual origin of the Earth's magnetic field is not completely understood. It is believed to be related to the motion of the Earth's inner core, which is mostly iron and nickel.

Scientists have been able to learn a great deal about the Earth's magnetic field and how it changes over time by studying patterns in magnetic rocks formed long ago. Some minerals have magnetic properties and are affected by the Earth's magnetism. In molten (hot liquid) rocks, the magnetic mineral particles line up in the direction of the Earth's magnetic poles. When the molten rocks harden, a permanent record of the Earth's magnetism remains in the rocks. Scientists have discovered that the history of the Earth's magnetism is recorded in magnetic stripes in the rocks. Although the stripes cannot be seen, they can be detected by special instruments. The pattern of the stripes reveals that the magnetic poles of the Earth have reversed themselves completely many times throughout Earth's history—every half-million years or so.

**Figure 2–9** *When volcanic lava hardens into rock, the direction of the Earth's magnetic field at that time is permanently recorded.*



## ANNOTATION KEY

### Answers

1 No. It points to the magnetic south pole, which does not exactly align with the geographic North Pole. (Interpreting illustrations)

### Integration

1 Earth Science: Geology. See *Exploring the Universe*, Chapter 3.

2 Earth Science: Geology. See *Exploring Planet Earth*, Chapter 5.

## PROBLEM SOLVING

### MIX-UP IN THE LAB

Students should be able to determine that the photograph shows a pattern of random magnetic domains and that therefore, the unlabeled object is not a magnet. If it were a magnet, the magnetic domains would be aligned in the same direction. The simplest test that the laboratory assistant could perform to confirm this conclusion would be to place metal items near the object and see if they are attracted to it, as they would be if the object were a magnet.

addition, the magnetic south pole is located near the geographic North Pole, and the magnetic north pole is located near the geographic South Pole. Use the world globe and the magnet again to demonstrate these facts. Explain that the north pole of a compass points toward the geographic North Pole, but because a magnet is attracted to an opposite pole, not a like pole, the north pole of the compass must be pointing to the magnetic south pole. Align the magnet in the proper direction and use a compass or a second magnet to reinforce this concept.

### CONTENT DEVELOPMENT

There is strong geological evidence that the Earth's north and south magnetic poles have "switched" a number of times in the past. Some scientists who have examined this evidence, which involves the orientation of magnetic minerals at different strata, think that another switch of magnetic poles may occur in the not-too-distant future.

### • • • • Integration • • • •

Use the discussion of the magnetic properties of molten rock to integrate geology concepts into your lesson.

### REINFORCEMENT/RETEACHING

Students might wish to sketch or obtain flat maps of the Earth and label the magnetic poles. They can also draw in compasses at different geographic locations on the map and show the directions in which the needles point.

## INTEGRATION

### EARTH SCIENCE

Recent space probes, such as *Voyager 1* and *Voyager 2*, have revealed interesting details about the magnetic properties of other planets. Jupiter, for example, has an extremely strong magnetic field. The magnetosphere of this planet is one of the largest field "structures" in the solar system, and the temperatures reached by excited atomic particles in parts of this field are the highest yet measured.

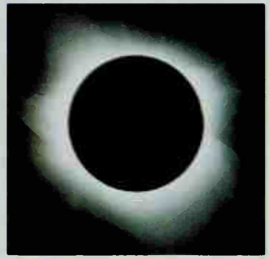
## HISTORICAL NOTE

### "MAGICAL" COMPASS

Compasses have had a great inspirational effect on a number of scientists in the past. Albert Einstein, for example, in describing his early childhood, wrote that his favorite toy was a compass needle given to him by his father. Einstein claimed that he never lost the sense of scientific wonder that he first felt when he played with that "magical" needle.

**Figure 2-10** *Without the use of compasses, early discoverers would have been unable to chart their courses across the seas and make maps. This photograph shows the earliest surviving Portuguese compass.*

**Figure 2-11** *A total solar eclipse provides a glimpse of the sun's corona. The flares of the solar corona are shaped by the sun's magnetic field.*



## Compasses

If you have ever used a compass, you know that a compass needle always points north. The needle of a compass is magnetized. It has a north pole and a south pole. The Earth's magnetic field exerts a force on the needle just as it exerts a force on a bar magnet hanging from a string.

The north pole of a compass needle points to the North Pole of the Earth. But to exactly which north pole? As you have learned, like poles repel and unlike poles attract. So the magnetic pole of the Earth to which the north pole of a compass points must actually be a magnetic south pole. In other words, the north pole of a compass needle points toward the geographic North Pole, which is actually the magnetic south pole. The same is true of the geographic South Pole, which is actually the magnetic north pole.

The Earth's magnetic poles do not coincide directly with its geographic poles. Scientists have discovered that the magnetic south pole is located in northeastern Canada, about 1500 kilometers from the geographic North Pole. The magnetic north pole is located near the Antarctic Circle. The angular difference between a magnetic pole and a geographic pole is known as magnetic variation, or declination. The extent of magnetic variation is not the same for all places on the Earth. Near the equator, magnetic variation is slight. As you get closer to the poles, the error increases. This must be taken into account when using a compass.

## Other Sources of Magnetism in the Solar System

Magnetic fields have been detected repeatedly throughout the galaxy. In addition to Earth, several other planets produce magnetic fields. The magnetic field of Jupiter is ten times greater than that of Earth. Saturn also has a very strong magnetic field. Like Earth, the source of the field is believed to be related to the planet's core.

The sun is another source of a magnetic field. The solar magnetic field extends far above the sun's surface. Streamers of the sun's corona (or outermost



## 2-2 (continued)

### CONTENT DEVELOPMENT

Because the Earth's magnetic south pole is located in northeastern Canada, the divergence of compasses from true north in the United States is greater in the northwestern part of the country. Compasses in the state of Washington, for example, point in a more or less northeastward, rather than northward, direction. In parts of Alaska, compasses actually point eastward!

**• • • • Integration • • • •**

Use the photograph of the early compass to integrate social studies concepts into your science lesson.

### INDEPENDENT PRACTICE

▶ *Activity Book*

Students can learn about the connection between the sun and the Earth's magnetosphere by completing the chapter activity Van Allen Radiation Belts. They will research the location and importance of these belts.

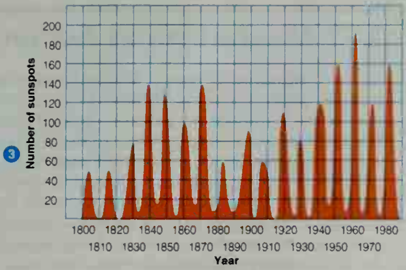
### CONTENT DEVELOPMENT

Explain that Jupiter has a gigantic magnetic field, called the magnetosphere, that stretches millions of kilometers from the planet. Jupiter's magnetosphere is probably caused by a liquid metallic layer around the planet's core. Saturn's huge magnetic field is second in size to Jupiter's.

Explain that sunspots are actually storms that occur on the sun's surface. Because sunspots are cooler than surrounding areas, they appear as dark patches. Some are many thousands of kilometers wide. Periods of heavy sunspot activity can interfere with communication systems on Earth, and astronomers are convinced that sunspot activity has an effect on Earth's weather and climate.

**• • • • Integration • • • •**

Use the discussion of magnetic fields on other planets to integrate concepts of astronomy into your lesson.




layer) trace the shape of the field. Within specific regions of the sun are very strong magnetic fields. Where magnetic lines of force break through the sun's surface, the temperature of the surface gases is lowered somewhat. These cooler areas appear as dark spots on the surface of the sun. These dark areas are known as sunspots. Sunspots always occur in pairs, each one of the pair representing the opposite poles of a magnet. The annual number of sunspots varies in an eleven-year cycle. The cycle is believed to be related to variations in the sun's magnetic field. Every eleven years the sun's magnetic field reverses, and the north and the south poles switch.

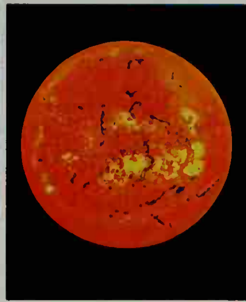


**Figure 2–12** *The dark regions on the surface of the sun, or sunspots, are produced by the sun's magnetic field. The pattern of sunspots changes regularly in an 11-year cycle. Notice from the graph how the number of sunspots rises and falls.*

## FIND OUT BY DOING

*Cork-and-Needle Compass*

**1.** Fill a nonmetal bowl about two-thirds full with water.

**2.** Magnetize a needle by stroking it with one end of a magnet.

**3.** Float a cork in the water; then place the needle on the cork. You may need to tape the needle in place.

**4.** Hold a compass next to the bowl. Compare its needle with the needle on the cork.

■ Explain how the cork-and-needle compass works. What is one disadvantage of a cork-and-needle compass?

## 2–2 Section Review

1. In what ways is the Earth like a magnet?
2. How does a compass work?
3. What does it mean to say that the Earth's geographic North Pole is really near the magnetic south pole?
4. What is meant by magnetic declination?
5. How are sunspots related to the sun's magnetic field?

**Connection—*Astronomy***

6. If the magnetic field of Earth is related to its inner core, how can astronomers learn about the inner cores of distant planets?



### ANNOTATION KEY

Integration
1 Social Studies
2 Earth Science: Astronomy. See *Exploring the Universe,* Chapter 2.
3 Mathematics

### FIND OUT BY DOING

CORK-AND-NEEDLE COMPASS

**Discovery Learning**

***Skills: Manipulative, observing, inferring***

***Materials: glass bowl, steel needle, cork, magnet, compass***

By magnetizing the needle, students are able to observe the effect of the magnetized needle on a compass. Students will immediately note that the needle and the compass point in the same direction. If they move the compass closer to the needle, however, they will note either a deflection or an attraction, depending on whether like poles or unlike poles are brought near each other.

The occurrence of sunspots is believed to be related to variations in the sun's magnetic field.

6. Astronomers can use what they know about Earth's inner core and its magnetic field and the data about other planets' magnetic fields to deduce information about those planets' inner cores.

Use the graph of sunspot activity to integrate mathematics concepts into your science lesson.

### INDEPENDENT PRACTICE

**Section Review 2-2**

1. The Earth exerts magnetic forces on magnets and compasses and is surrounded by a magnetic field.
2. The Earth's magnetic field exerts a force on the magnetized compass needle, causing it to line up in a north-south direction.
3. The north pole of a magnet is attracted to the geographic North Pole of the Earth. Because opposite poles attract, the geographic North Pole must actually be a magnetic south pole.
4. The error in a compass caused by the difference in location between the Earth's magnetic and geographic poles.
5. Sunspots are very strong magnetic fields within certain regions of the sun.

### REINFORCEMENT/RETEACHING

Review students' responses to the Section Review questions. Reteach any material that is still unclear, based on students' responses.

### CLOSURE

▶ *Review and Reinforcement Guide*

Students may now complete Section 2–2 in the *Review and Reinforcement Guide.*

# 2-3 Magnetism in Action

## MULTICULTURAL OPPORTUNITY 2-3

Have your students build a model of a magnet. A block of Styrofoam can represent the magnetic steel bar. Ask them to cut out of heavy stock paper small arrows. Using straight pins, place the arrows onto the block of Styrofoam. The arrows can represent the spinning orientation of the electrons in the metal bar. A magnet can be represented by having all the arrows pointed in the same direction. A nonmagnetic object is represented by arrows, with some arrows pointing in one direction and others in the opposite direction. You might ask students if they can use this model to explain why a falling magnet will change its orientation.

## ESL STRATEGY 2-3

Have students complete the following paragraph on magnetism in action. They should fill in the missing information by choosing from the following list:

magnetosphere
aurora
solar wind with charged particles
Van Allen radiation belts
Earth's magnetic field

The ______ is blocked by the ______, which is called the ______. When charged particles do penetrate it, they are found in two large regions known as the ______. As the particles approach the Earth's surface, they cause the air to glow; this phenomena is called ______.

**Guide for Reading**

*Focus on this question as you read.*

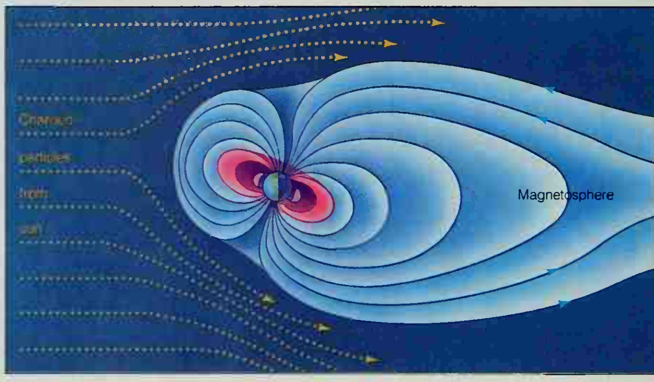
▶ *How do magnetic fields alter the motion of charged particles?*

## 2–3 Magnetism in Action

You learned in Chapter 1 that when a charged particle enters an electric field, an electric force is exerted on it (it is either pulled or pushed away). But what happens when a charged particle enters a magnetic field? The magnetic force exerted on the particle, if any, depends on a number of factors, especially the direction in which the particle is moving. **If a charged particle moves in the same direction as a magnetic field, no force is exerted on it. If a charged particle moves at an angle to a magnetic field, the magnetic force acting on it will cause it to move in a spiral around the magnetic field lines.** See Figure 2–14.

**SOLAR WIND** The Earth and the other planets are immersed in a wind of charged particles sent out by
1 the sun. These particles sweep through the solar system at speeds of around 400 kilometers per second. If this tremendous amount of radiation (emitted charged particles) reached the Earth, life as we know it could not survive.

**Figure 2–13** *Because of its interaction with the solar wind, the Earth's magnetic field differs from that of a bar magnet. The solar wind causes the magnetosphere to stretch out into a tail shape on the side of the Earth that is experiencing nighttime.*

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## TEACHING STRATEGY 2-3

### CONTENT DEVELOPMENT

Refer students to Figure 2–13, which shows the Earth's magnetosphere. Explain the interaction between the magnetosphere and the "solar wind," or charged particles streaming outward from the sun. Explain that the asymmetrical shape of the magnetosphere, which streams outward away from the sun, is due to this interaction with the charged particles.

**● ● ● ● Integration ● ● ● ●**

Use the discussion about the solar wind to integrate earth science concepts of astronomy into your lesson.

### GUIDED PRACTICE

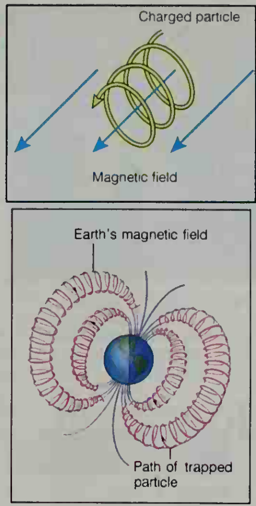
**Skills Development**

***Skills: Interpreting diagrams, drawing conclusions***

Have students reread the boldface sentences in the first paragraph on page P56. Then refer them to Figure 2–14. Have them identify the movement of the charged particles in the Van Allen radiation belts. (Spiral movement.)

- **From what direction did charged particles trapped in the Van Allen radiation belts move in Earth's magnetosphere? Explain your answer.** (From an angle, because the trapped particles move in a spiral around the magnetic field lines.)
- **If a charged particle moves parallel to**

**Figure 2-14** *Charged particles from the sun become trapped in spiral paths around the Earth's magnetic field lines. What are the two regions in which the particles are confined called?* ❶




Fortunately, however, these charged particles are deflected by the Earth's magnetic field. The magnetic field acts like an obstacle in the path of the solar wind. The region in which the magnetic field of the Earth is found is called the **magnetosphere.** Without the solar wind, the magnetosphere would look like the lines of force surrounding a bar magnet. However, on the side of the Earth facing away from the sun the magnetosphere is blown into a long tail by the solar wind. The solar wind constantly reshapes the magnetosphere as the Earth rotates on its axis.

Sometimes charged particles from the sun do penetrate the field. The particles are forced to continually spiral around the magnetic field lines, traveling back and forth between magnetic poles. Generally, these charged particles are found in two large regions known as the Van Allen radiation belts, named for their discoverer, James Van Allen.

When a large number of these particles get close to the Earth's surface, they interact with atoms in the atmosphere, causing the air to glow. Such a glowing region is called an **aurora.** Auroras are continually seen near the Earth's magnetic poles, since these are the places where the particles are closest to the Earth. The aurora seen in the northern hemisphere is known as the aurora borealis, or northern lights. In the southern hemisphere, the aurora is known as the aurora australis, or southern lights. ❷

Many scientists believe that short-term changes in the Earth's weather are influenced by solar particles and their interaction with the Earth's magnetic field. In addition, during the reversal of the Earth's magnetic field, the field is somewhat weakened. This allows more high-energy particles to reach the Earth's surface. Some scientists hypothesize that these periods during which the magnetic field reversed might have caused the extinction of certain species of plants and animals.

**Figure 2-15** *A band of colors called an aurora dances across the sky near the Earth's magnetic poles. This one is in northern Alaska. Why do auroras form?* ❷



## ANNOTATION KEY

### Answers

❶ Van Allen radiation belts. (Relating facts)

❷ Radiation from the sun collides with particles in the atmosphere to produce a sheet of light called an aurora. (Relating concepts)

### Integration

❶ Earth Science: Astronomy. See *Exploring the Universe,* Chapter 1.

❷ Physical Science: Light. See *Sound and Light,* Chapter 3.

## ECOLOGY NOTE

### LIGHT POLLUTION

The aurora borealis is a magnificent display of light. Unfortunately, many people are prevented from seeing this display because of light pollution. Suggest that students research to find out what light pollution is and how it might be controlled so that people can enjoy such phenomena as the aurora. Have students consider how light pollution may affect scientific study at observatories.

**the magnetosphere, will a force be exerted on it?** (No. Because it is moving in the same direction of the magnetosphere.)

### CONTENT DEVELOPMENT

The Earth is largely protected from high-intensity radiation from the sun by broad belts in the Earth's magnetosphere called the Van Allen radiation belts. These belts, named for scientist James Van Allen, whose work led to their discovery, trap high-energy protons and electrons. The belts encircle the Earth at varying levels, starting at roughly 1000 kilometers above the Earth's surface and extending to roughly 20,000 kilometers or more. When a large number of the charged particles penetrate the Van Allen radiation belts and escape into the upper atmosphere above Earth's polar regions, they collide with molecules in the atmosphere. The collision causes the atmospheric particles to give off light, known as an aurora.

### • • • • Integration • • • •

Use the information about the aurora to integrate concepts of light into your lesson.

## FIND OUT BY READING

### A LONELY VOYAGE

***Skill: Reading comprehension***

Point out to students that history books usually credit Admiral Robert Peary's expedition in 1909 as being the first expedition to reach the North Pole. Controversy arose, however, about whether Peary ever actually made it to the pole. William Hunt's book examines the controversy. After students read the book, encourage them to express opinions. Who do they believe was the leader of the first expedition to reach the North Pole?

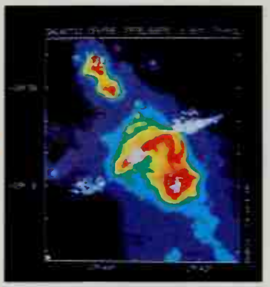
1 

**Figure 2–16** *This map of the constellation Sagittarius was made from information collected by a radio telescope.*

### FIND OUT BY READING

*A Lonely Voyage*

The dangerous quest to reach the North Pole was at one time only a vision in the minds of adventurous explorers. But during the 1800s several different explorers set out on difficult and sometimes fatal missions to the North Pole. Two different explorers reached the pole, but the matter of who arrived first still remains controversial. The answers lie in whether the explorers made appropriate corrections for magnetic declination. Read *To Stand at the Pole: The Dr. Cook-Admiral Peary North Pole Controversy* by William Hunt to discover the details of the story.

**ASTRONOMY** Radiation from particles spiraling around in magnetic fields also plays an important role in learning about the universe. Particles trapped by magnetic fields emit energy in the form of radio waves. Radioastronomers study the universe by recording and analyzing radio waves rather than light waves. In this way, scientists have been able to learn a great deal about many regions of the galaxy. For example, energy received from the Crab Nebula indicates that it is a remnant of a supernova (exploding star).

**NUCLEAR ENERGY** Utilizing the behavior of charged particles in magnetic fields may be a solution to the energy problem. A tremendous amount of energy can be released when two small atomic 2
nuclei are joined, or fused, together into one larger nucleus. Accomplishing this, however, has been impossible until now because it is extremely difficult to overcome the repulsive electric forces present when two nuclei approach each other. At high temperatures, atoms break up into a gaseous mass of charged particles known as plasma. In this state, nuclear reactions are easier to achieve. But the required temperatures are so high that the charged particles cannot be contained by any existing vessels. By using magnetic fields, however, scientists hope to create a kind of magnetic bottle to contain the particles at the required temperatures. Massive research projects are currently underway to achieve this goal.

## 2–3 Section Review

1. Describe what happens to a charged particle in a magnetic field.
2. How does the magnetosphere protect the Earth from the sun's damaging radiation?
3. What are Van Allen radiation belts? How are they related to auroras?
4. How might magnetic fields enable scientists to utilize energy from atomic nuclei?

**Connection—*Earth Science***

5. Why would a planet close to the sun have to possess a strong magnetic field in order to sustain life?



## 2–3 (continued)

### CONTENT DEVELOPMENT

Point out that today's nuclear power plants use heat energy from nuclear fission to produce electrical power. Nuclear fission is the splitting apart of an atomic nucleus, which releases energy. Nuclear fusion, the combining of two atomic nuclei, produces even more energy than fission. Scientists are trying to develop controlled fusion reactions to meet future energy needs. Because hydrogen from water would be used as the fuel in a nuclear fusion reactor, the fuel source is renewable and in large supply. The development of a magnetic bottle to contain the hydrogen particles so that fusion reactions could be produced at the required temperatures would help to meet energy needs with a renewable fuel source.

### ● ● ● ● Integration ● ● ● ●

Use the information about radio telescopes to integrate earth science concepts of astronomy into your lesson.

Use the information about the use of nuclear energy to integrate concepts of fusion into your lesson.

### ENRICHMENT

In 1990, chemists Stanley Pons and Martin Fleischmann claimed to have discovered cold fusion. The claim was quickly rejected. Have students investigate what cold fusion is and why the possibility of cold fusion excited scientists around the world.

### INDEPENDENT PRACTICE

#### Section Review 2–3

1. No force is exerted on a charged particle moving in the same direction as a magnetic field. A magnetic force will cause charged particles moving at an

# CONNECTIONS

## *Magnetic Clues to Giant-Sized Mystery* ❸

Have you ever looked at a world map and noticed that the Earth's landmasses look like pieces of a giant jigsaw puzzle? According to many scientists, all the Earth's land was once connected. How then, did the continents form?

In the early 1900s, a scientist named Alfred Wegener proposed that the giant landmass that once existed split apart and its various parts "drifted" to their present positions. His theory, however, met with great opposition because in order for it to be true, it would involve the movement of sections of the solid ocean floor. Conclusive evidence to support his *theory of continental drift* could come only from a detailed study of the ocean floor.

In the 1950s and 1960s, new mapping techniques enabled scientists to discover a large system of underwater mountains, called midocean ridges. These mountains have a deep crack, called a rift valley, running through their center. A great deal of volcanic activity occurs at the midocean ridges. When lava wells up through the rift valley and hardens into rock, new ocean floor is formed. This process is called *ocean-floor spreading.* This evidence showed that the ocean floor could indeed move.

Further evidence came from information about the Earth's magnetic field. When the molten rocks from the midocean ridges harden, a permanent record of the Earth's magnetism remains in the rocks. Scientists found that the pattern of magnetic stripes on one side of the ridge matches the pattern on the other side. The obvious conclusion was that as magma hardens into rocks at the midocean ridge, half the rocks move in one direction and the other half move in the other direction. If it were not for knowledge about magnetism and the Earth's magnetic field, such a conclusion could not have been reached. Yet thanks to magnetic stripes, which provide clear evidence of ocean-floor spreading, the body of scientific knowledge has grown once again.

ANNOTATION KEY

Integration

❶ Earth Science: Radio Telescopes. See *The Nature of Science,* Chapter 3.

❷ Physical Science: Fusion. See *Chemistry of Matter,* Chapter 5.

❸ Earth Science: Continental Drift. See *Dynamic Earth,* Chapter 3.

CONNECTIONS

MAGNETIC CLUES TO GIANT-SIZED MYSTERY

You might make copies of a world map and encourage students to try to fit the continents together in a large landmass as an introductory activity for the Connections feature. You may also want to demonstrate the concept of the magnetic stripes supporting the concept of ocean-floor spreading by drawing horizontal lines on a sheet of paper and then tearing the paper vertically. Students should see that the lines on both sides of the paper are similar, just as the magnetic stripes on both sides of the midocean ridges are similar.

If you are teaching thematically, you may want to use the Connections feature to reinforce the themes of evolution and patterns of change.

**Integration:** Use the Connections feature to integrate earth science concepts of continental drift into your lesson.

angle to a magnetic field to move in a spiral around the magnetic-field lines.

2. It traps charged particles and forces them to spiral around the magnetic-field lines, thus preventing them from reaching the Earth's surface.

3. The Van Allen radiation belts are two large regions where most charged particles are found in the magnetosphere. When a large number of charged particles in the belt get close to Earth, they collide with particles in the atmosphere. The collision causes the aurora.

4. The magnetic fields may be used to create a magnetic bottle that could contain particles for fusion at the required temperatures.

5. Without a strong magnetic field, the charged particles of the sun would reach the planet and destroy the life on it.

### REINFORCEMENT/RETEACHING

Monitor students' responses to the Section Review questions. If students appear to have difficulty with any of the concepts, review the appropriate material.

### CLOSURE

▶ *Review and Reinforcement Guide*

Students may now complete Section 2–3 of the *Review and Reinforcement Guide.*

# Laboratory Investigation

## PLOTTING MAGNETIC FIELDS

### BEFORE THE LAB

Gather all materials at least one day prior to the investigation. You should have enough supplies to meet your class needs, assuming three to six students per group.

### PRE-LAB DISCUSSION

Have students read the complete laboratory procedure.

- **What is the purpose of the laboratory investigation?** (To plot and compare the magnetic fields of magnets.)
- **Why do you think two different types of magnets are used in the investigation?** (For comparison purposes.)
- **Do you think the compass needle will point in different directions as you move the compass around the magnets?** (Answers will vary; some students may suggest that the needle will move because the strength of the magnetic force is greater at the poles.)

# Laboratory Investigation

## Plotting Magnetic Fields

### Problem

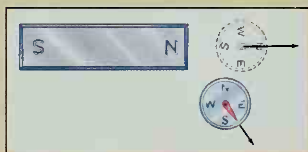
How can the lines of force surrounding a bar magnet be drawn?

### Materials *(per group)*

| | |
|---|---|
| bar magnet | horseshoe magnet |
| sheet of white paper | compass |
| pencil | |

### Procedure

1. Place a bar magnet in the center of a sheet of paper. Trace around the magnet with a pencil. Remove the magnet and mark the ends of your drawing to show the north and the south poles. Put the magnet back on the sheet of paper in its outlined position.
2. Draw a mark at a spot about 2 cm beyond the north pole of the magnet. Place a compass on this mark.
3. Note the direction that the compass needle points. On the paper, mark the position of the north pole of the compass needle by drawing a small arrow. The arrow should extend from the mark you made in step 2 and point in the direction of the north pole of the compass needle. This arrow indicates the direction of the magnetic field at the point marked. See the accompanying diagram.




4. Repeat steps 2 and 3 at 20 to 30 points around the magnet. You should have 20 to 30 tiny arrows on the paper when you have finished.
5. Remove the magnet from the paper. Observe the pattern of the magnetic field you have plotted with your arrows.
6. Using a clean sheet of paper, repeat steps 1 through 5 using a horseshoe magnet.

### Observations

1. Describe the pattern of arrows you have drawn to represent the magnetic field of the bar magnet. How does it differ from that of the horseshoe magnet?
2. From which pole does the magnetic field emerge on the bar magnet? On the horseshoe magnet?

### Analysis and Conclusions

1. What evidence is there that the magnetic field is strongest near the poles of a magnet?
2. What can you conclude about the path of magnetic field lines between the poles of any magnet?
3. **On Your Own** The pattern of magnetic field lines for a bar magnet will change if another bar magnet is placed near it. Design and complete an investigation similar to this one in which you demonstrate this idea for both like poles and unlike poles.



### TEACHING STRATEGY

1. You may want to demonstrate the laboratory procedure to help groups become familiar with the process.
2. Tell students to keep the magnet they are not plotting away from the work area so that its magnetic force does not interfere with the plotting of the other magnet.
3. Have groups compare their patterns of arrows to note whether all groups plotted similar patterns.

### DISCOVERY STRATEGIES

Discuss how the investigation relates to the chapter ideas by asking open questions similar to the following:

- **How are the forces of magnetism in all magnets alike?** (The magnetic forces are strongest at the poles and weaker around the rest of the magnet.)
- **How far away would a paper clip have to be from a magnet not to be attracted to it?** (Just outside the magnetic field. The distance would vary, depending on the strength of the magnetic force.)
- **Could you plot the magnetic field of the magnets without a compass? Explain.** (Answers will vary. Lead students to understand that they could use iron filings, for example, to plot the field of magnetism of the magnets.)

### OBSERVATIONS

1. The pattern around the bar magnet arcs around each pole, with more arrows

# Study Guide

## Summarizing Key Concepts

### 2–1 The Nature of Magnets

▲ Every magnet has two poles—a north pole and a south pole. Like magnetic poles repel each other; unlike poles attract each other.

▲ The region in which magnetic forces can act is called a magnetic field. Magnetic fields are traced by magnetic lines of force.

▲ Magnetic domains are regions in which the magnetic fields of all the atoms line up in the same direction. The magnetic domains of a magnet are aligned. The magnetic domains of unmagnetized material are arranged randomly.

▲ Magnetism is the force of attraction or repulsion exerted by a magnet through its magnetic field.

### 2–2 The Earth As a Magnet

▲ The Earth is surrounded by a magnetic field that is strongest around the magnetic north and the south poles.

▲ A compass needle does not point exactly to the Earth's geographic poles. It points to the magnetic poles. The difference in the location of the Earth's magnetic and geographic poles is called magnetic declination.

▲ Sunspots on the surface of the sun are related to the sun's magnetic field.

### 2–3 Magnetism in Action

▲ The deflection of charged particles in a magnetic field is responsible for several phenomena: the protection of the Earth from solar wind; radio astronomy; and future applications of nuclear reactions to produce energy.

▲ The region in which the magnetic field of Earth is exerted is known as the magnetosphere.

▲ Some charged particles from the sun become trapped by Earth's magnetic field. They are located in two regions known as the Van Allen radiation belts. If charged particles reach Earth's surface, usually at the poles, they create auroras.

## Reviewing Key Terms

*Define each term in a complete sentence.*

### 2–1 The Nature of Magnets

magnetism
pole
magnetic field
magnetic domain

### 2–3 Magnetism in Action

magnetosphere
aurora



closer together near the poles. The pattern is somewhat oval. The pattern of the arrows around the horseshoe magnet also radiates toward the poles, with more arrows closer together near the poles. The pattern is arclike between the two poles.
2. In both cases, the direction of the magnetic field is from the north to the south pole.

### ANALYSIS AND CONCLUSIONS

1. More arrows are located there, and they are closer together.
2. The path radiates toward the poles.
3. Investigations should be designed so that the attraction of unlike poles and the repulsion of like poles are clearly delineated in the plot.

### GOING FURTHER: ENRICHMENT

**Part 1**

Have students design an experiment demonstrating the range of the magnetic attraction of magnets of different strengths. Have them measure the range from the center of the magnet and at each pole. Suggest that they use these materials in their experiment: a paper clip, three bar magnets of different strengths, a metric ruler, and a data table.

**Part 2**

Have students imagine that they are located in a field on a cloudy day and that they do not know which direction they are facing. Ask them to tell how they could determine the direction that they are facing if all they had with them was a bar magnet and a string.

# Chapter Review

### ALTERNATIVE ASSESSMENT

The *Prentice Hall Science* program includes a variety of testing components and methodologies. Aside from the Chapter Review questions, you may opt to use the Chapter Test or the Computer Test Bank Test in your *Test Book* for assessment of important facts and concepts. In addition, Performance-Based Tests are included in your *Test Book*. These Performance-Based Tests are designed to test science-process skills, rather than factual content recall. Since they are not content dependent, Performance-Based Tests can be distributed after students complete a chapter or after they complete the entire textbook.

### CONTENT REVIEW

**Multiple Choice**

1. c
2. b
3. d
4. a
5. b
6. d
7. d

### True or False

1. T
2. F, repel
3. T
4. F, can
5. T
6. T
7. F, magnetic pole
8. T

### Concept Mapping

Row 1: act in a

Row 2: Magnetic lines of force

Row 3: Magnetic domains; South Pole

# Chapter Review

## Content Review

### Multiple Choice

*Choose the letter of the answer that best completes each statement.*

1. The region in which magnetic forces act is called a
   a. line of force. b. pole. c. magnetic field. d. field of attraction.
2. A region in a magnet in which the magnetic fields of atoms are aligned is a
   a. ferrum. b. domain. c. compass. d. magnetosphere.
3. The idea of the Earth as a magnet was first proposed by
   a. Dalton. b. Faraday. c. Oersted. d. Gilbert.
4. The results of the sun's magnetic field can be seen as
   a. sunspots. b. solar winds. c. magnetic stripes. d. ridges.
5. Which of the following is not a magnetic material?
   a. lodestone b. glass c. cobalt d. nickel
6. The region of the Earth's magnetic field is called the
   a. atmosphere. b. stratosphere. c. aurora. d. magnetosphere.
7. Charged particles from the sun that get close to the Earth's surface produce
   a. supernovas. b. volcanoes. c. plasma. d. auroras.

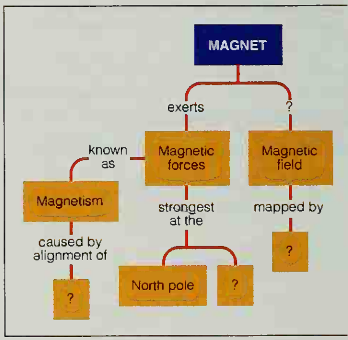
### True or False

*If the statement is true, write "true." If it is false, change the underlined word or words to make the statement true.*

1. The north pole of a magnet suspended horizontally from a string will point north.
2. Like poles of a magnet attract each other.
3. The region in which magnetic forces act is called a magnetic field.
4. Steel cannot be magnetized.
5. In a magnetized substance, magnetic domains point in the same direction.
6. Magnetic domains exist because of the magnetic fields produced by the motion of electrons.
7. A compass needle points to the Earth's geographic pole.
8. The Earth's magnetic field protects against the harmful radiation in solar winds.

### Concept Mapping

*Complete the following concept map for Section 2–1. Refer to pages P6–P7 to construct a concept map for the entire chapter.*




62 ■ P

## CONCEPT MASTERY

1. Magnetic poles are the ends of a magnet where magnetic effects are strongest. Like poles repel each other; unlike poles attract each other.

2. When a magnet is cut in half, two smaller magnets, each with a north pole and a south pole, are produced because magnetic poles always appear in pairs.

3. The magnetic lines of force extend from one pole of a magnet to the other in the area over which magnetic force is exerted.

4. A magnetic domain is a region in which magnetic fields of atoms align in the same direction.

5. The magnetic stripes in molten rocks aligned with the Earth's magnetic poles at the time that they solidified. The alignment of the stripes provides evidence of changes in Earth's magnetic field over time.

6. Materials are magnetic if they have aligned domains. Unmagnetized materials have domains arranged randomly. A substance is magnetized by causing the domains to become aligned. A substance loses magnetism when the domains rearrange in random order.

7. Like a bar magnet because it exerts magnetic forces and the magnetic field is strongest at the poles.

8. Jupiter is a source of magnetism with a magnetic field ten times greater than that of Earth's. Saturn also has a very strong magnetic field. The sun is another source of magnetic fields that extend far beyond the sun's surface. Sunspots are specific areas of strong magnetic fields on the sun.

9. An aurora is produced when charged particles come close to Earth near the poles and collide with particles in the atmosphere. The collision results in the lights known as an aurora.

10. The trapping of charged particles in Earth's magnetosphere helps to prevent them from escaping into Earth's atmosphere. Charged particles in magnetic fields may also help scientists develop energy-producing technologies through nuclear fusion.

## CRITICAL THINKING AND PROBLEM SOLVING

1. The diagrams should show that the lines of force repel each other when like poles are placed together and attract

## Concept Mastery

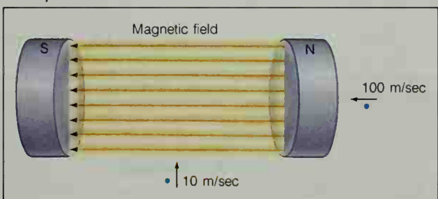
*Discuss each of the following in a brief paragraph.*

1. What are magnetic poles? How do magnetic poles behave when placed next to each other?
2. What happens when a magnet is cut in half? Why?
3. How is a magnetic field represented by magnetic field lines of force?
4. How are magnetic domains related to the atomic structure of a material?
5. How can evidence of changes in the Earth's magnetic field be found in rocks?
6. Why are some materials magnetic while others are not? How can a material be magnetized? How can a magnet lose its magnetism?
7. Like what type of magnet does the Earth act? How?
8. Describe several sources of magnetism in the solar system.
9. Explain how an aurora is produced.
10. What is the significance of the fact that charged particles can become trapped by magnetic fields?

## Critical Thinking and Problem Solving

*Use the skills you have developed in this chapter to answer each of the following.*

1. **Making comparisons** How do the lines of force that arise when north and south poles of a magnet are placed close together compare with the lines of force that arise when two like poles are placed close together? Use a diagram in your explanation.
2. **Applying concepts** Why might an inexperienced explorer using a compass get lost near the geographic poles?
3. **Making comparisons** One proton is traveling at a speed of 100 m/sec parallel to a magnetic field. Another proton is traveling at a speed of 10 m/sec perpendicular to the same magnetic field. Which one experiences the greater magnetic force? Explain.




4. **Identifying patterns** Describe the difference between a permanent magnet and a temporary magnet.
5. **Relating cause and effect** Stroking a material with a strong magnet causes the material to become magnetic. Explain what happens during this process.
6. **Making inferences** Why might a material be placed between two other materials so that magnetic lines of force are not allowed to pass through?
7. **Using the writing process** Write a poem or short story describing the importance of magnets in your daily life. Include at least five detailed examples.



each other when unlike poles are placed close together.
2. The explorer might not know that magnetic variation increases as you get closer to the poles.
3. The one traveling perpendicular to the magnetic field because it is at an angle to the field and so a force is exerted on it. No force is exerted on the particle traveling parallel to the field.
4. A material that loses its magnetism quickly is a temporary magnet. A material that retains its magnetism for a long time is a permanent magnet.
5. During this process the domains of the material align with one another in the same direction, causing the material to become magnetized.
6. Answers will vary but should reflect the understanding that the material is placed there to prevent the interaction of the magnetic fields.
7. Poems or stories will vary but should be consistent with the information in the chapter. As an important use of magnets in their daily life, students might identify magnets in freezer doors, which, by keeping the door closed, help to prevent perishable items in the freezer from spoiling.

### KEEPING A PORTFOLIO

You might want to assign some of the Concept Mastery and Critical Thinking and Problem Solving questions as homework and have students include their responses to unassigned questions in their portfolio. Students should be encouraged to include both the question and the answer in their portfolio.

### ISSUES IN SCIENCE

The following issues can be used as springboards for discussion or given as writing assignments:

1. People on Earth are protected from some harmful charged particles by the Van Allen radiation belts. Astronauts traveling beyond the belts do not have the protection of the Van Allen belts. Their spacesuits and spaceships must be made of material that will help to protect them from these harmful particles. If the protective materials are penetrated, the astronauts might be exposed to the harmful particles. Do you think space exploration by astronauts should continue if there is even a remote possibility of exposure to the harmful rays?
2. Research in nuclear fusion is costly and time consuming. Should the research continue because alternative fuel sources are needed, or should the research be discontinued and the money and time allocated to address other needs, such as cures for fatal diseases?

# Chapter 3 ELECTROMAGNETISM

| SECTION | LABORATORY INVESTIGATIONS AND DEMONSTRATIONS |
|---|---|
| **3–1 Magnetism From Electricity**<br>pages P66–P71 | **Student Edition**<br>Electromagnetism, p. P82<br>**Teacher Edition**<br>Observing Magnetism, p. P64d |
| **3–2 Electricity From Magnetism**<br>pages P72–P81 | **Laboratory Manual**<br>Studying Electromagnetic Induction<br>**Teacher Edition**<br>People Have the Power, p. P64d |
| **Chapter Review**<br>pages P82–P85 | |

*All materials in the Chapter Planning Guide Grid are available as part of the Prentice Hall Science Learning System.

## OUTSIDE TEACHER RESOURCES

### Books

Branley, Franklin M. *The Electromagnetic Spectrum,* Crowell.

Edminster, Joseph. *Schaum's Outline of Electromagnets,* McGraw-Hill.

Irving, Robert. *Electromagnetic Waves,* Knopf.

### Audiovisuals

*Electromagnetism,* 8-mm film loop, Prentice-Hall Media

Electromagnetism, courseware, Prentice-Hall Media

| OTHER ACTIVITIES | MULTIMEDIA |
|---|---|
| **Activity Book**<br>Chapter Discovery: Making an Electric Motor<br>**Student Edition**<br>Find Out by Doing: Making an Electromagnet, p. P67<br>Find Out by Doing: Changing Direction, p. P69<br>**Review and Reinforcement Guide**<br>Section 3–1 | **Courseware**<br>Electromagnetism (Supplemental)<br>**English/Spanish Audiotapes**<br>Section 3–1 |
| **Activity Book**<br>ACTIVITY: Effect of a Magnet on a Television<br>ACTIVITY: Transformers<br>ACTIVITY: Electricity ↔ Magnetism<br>**Student Edition**<br>Find Out by Doing: Compass Interference, p. P73<br>Find Out by Writing: The History of Electromagnetism, p. P74<br>Find Out by Doing: An Electrifying Experience, p. P78<br>**Review and Reinforcement Guide**<br>Section 3–2 | **Video**<br>Electricity and Magnetism<br>**English/Spanish Audiotapes**<br>Section 3–2 |
| **Test Book**<br>Chapter Test<br>Performance-Based Test | **Test Book**<br>Computer Test Bank Test |

*Electromagnets,* filmstrip or videocassette, Encyclopaedia Britannica Education

*Electromagnets and Their Uses,* 16-mm film, Coronet Film and Video

# Chapter 3 ELECTROMAGNETISM

## CHAPTER OVERVIEW

Electromagnetism is a term used to describe the relationship between electricity and magnetism. The experiments of Hans Christian Oersted illustrated that an electric current gives rise to a magnetic field whose direction depends on the direction of the applied current. These experiments led to the development of temporary magnets called electromagnets; the electric motor, a device that converts electrical energy into mechanical energy; and the galvanometer, an instrument used to detect small currents.

Faraday and Henry experimented with electromagnetic induction, or the production of a current by the motion of a conductor across magnetic lines of a force in a magnetic field. These experiments led to the development of the generator—a device in which principles of electromagnetic induction are applied to convert mechanical energy into electrical energy such as alternating current—and transformers—devices that increase or decrease the voltage of an alternating current.

## 3-1 MAGNETISM FROM ELECTRICITY

### THEMATIC FOCUS

The purpose of this section is to introduce students to the concept of obtaining magnetism from electricity. More than 150 years ago, an experiment by the Danish physicist Hans Christian Oersted led to an important scientific discovery about the relationship between electricity and magnetism, known now as electromagnetism. Oersted found that an electric current flowing through a wire gives rise to a magnetic field whose direction depends on the direction of the applied current. This discovery led to the development of the electromagnet.

A number of practical devices use the concept of electromagnetism in their design, for example, the electric motor. An electric motor changes electric energy into mechanical energy and contains an electromagnetic armature that is free to rotate on a shaft within a permanent magnet that is held in a fixed position. When current flows into the armature, the ends of the armature become magnetic poles. The poles of the armature then begin to rotate to the opposite poles of the fixed magnet (because opposites attract). Just before the armature reaches the poles, the current through the wire changes direction, causing the poles of the armature to switch. Once again, the opposite poles of the armature and the fixed magnet attract, so the armature continues to rotate. This process occurs over and over again, keeping the armature in continuous rotation. The alternating current supplied to an electric motor switches the poles of the armature 120 times each second, or switches complete cycles (back and forth) 60 times each second. Consequently, alternating current is referred to as 60-hertz or 60-cycle current.

The armature of an electric motor is usually connected to a shaft, and the spinning armature causes the shaft to spin, enabling the motor to do work. The shaft can be connected to pulleys, fan blades, wheels, or almost any other device that uses mechanical energy. Sewing machines, refrigerators, vacuum cleaners, power saws, subway trains, and most industrial machinery are a few of the many devices that would be practically impossible to design without electric motors.

The themes that can be focused on in this section are energy, stability, unity and diversity, and patterns of change.

***Energy:** The principles of electromagnetism can be applied to convert one form of energy into another form of energy.

***Stability:** A magnetic field will always exist around a current.

**Unity and diversity:** Electric motors use electromagnets to convert one form of energy into another—electrical energy into mechanical energy.

**Patterns of change:** An electric current flowing through a wire will create a magnetic field whose direction depends on the direction of the current.

### PERFORMANCE OBJECTIVES 3-1

**1. Describe Oersted's experiment on currents and magnetic fields and state the principle he discovered.**
**2. Define electromagnetism.**
**3. Explain the structure and function of electromagnets.**
**4. Describe the structure and use of electric motors.**
**5. Distinguish between direct and alternating current.**
**6. Describe the structure and use of galvanometers.**

### SCIENCE TERMS 3-1

**electromagnetism p. P66**
**solenoid p. P67**
**electromagnet p. P67**
**electric motor p. P69**
**galvanometer p. P70**

## 3-2 ELECTRICITY FROM MAGNETISM

### THEMATIC FOCUS

This section will introduce students to the concept that electricity can be produced from magnetism. This concept was investigated independently in 1831 by the English scientist Michael Faraday and the American scientist Joseph Henry. Because Faraday published his results first and investigated the concept in more detail, his work is better known.

Faraday's experiments showed that although a steady magnetic field produced no electric current, a changing magnetic field did produce an electric current. Such a current is called an induced current, and the process by which a current is produced by a changing magnetic field is called electromagnetic induction.

Faraday also conducted other experiments into the nature of electromagnetic induction, but the one common element in all his experiments was a changing magnetic field. In electromagnetic induction, it does not matter whether the magnetic field changes because the magnet moves, the current moves, or the current giving rise to the magnetic field changes. It matters only that a changing magnetic field is experienced.

An important application of electromagnetic induction is the generator. A generator is a device that converts mechanical energy into electrical energy. Generators that manufacture electricity in power plants account for about 99 percent of the electricity consumed in the United States. The electricity generated in power plants reaches its destination by traveling through wires, and the use of step-up and step-down tranformers has made this method of delivery more efficient.

Other important applications of electromagnetic induction include seismic devices called geophones and electromagnetic pumps for circulating blood.

The themes that can be focused on in this section are energy, scale and structure, systems and interactions, unity and diversity, and patterns of change.

***Energy:** Energy in the form of alternating current can travel from one place to another more efficiently with the use of transformers.

***Scale and structure:** Electric current is produced and used at low voltages, but it is most efficiently transmitted at high voltages. Transformers change the voltage of alternating current for practical use and distribution.

***Systems and interactions:** A magnetic field will exert a force on a wire that is carrying current.

**Unity and diversity:** Generators use electromagnets to convert one form of energy into another. A generator converts mechanical energy into electric energy.

**Patterns of change:** A changing magnetic field gives rise to an electric current.

## PERFORMANCE OBJECTIVES 3-2

**1. Describe Faraday's and Henry's experiments and state the principle of electromagnetism they discovered.**
**2. Define electromagnetic induction.**
**3. Describe the structure, operation, and uses of a generator.**
**4. Explain the production of alternating current.**
**5. Describe the structure, operation, and uses of step-up and step-down transformers.**

## SCIENCE TERMS 3-2

**induced current p. P73**
**electromagnetic induction p. P73**
**generator p. P74**
**transformer p. P78**

## Discovery Learning

### TEACHER DEMONSTRATIONS MODELING

#### Observing Magnetism

Obtain a cassette musical tape or a cassette videotape of which the recorded material is no longer needed. **Note:** *This demonstration will adversely affect the sound or picture quality of the previously recorded material you choose to use, although the tape can be rerecorded and reused again at any time in the future.* Play the tape for students so that they can see or hear the quality of the recorded material. Then allow a strong magnet or electromagnet to come into contact with the tape and its shell. After several seconds (or longer—depending on the strength of your magnet), play back the area of the tape that came into contact with the magnet, and some of the remaining tape.

• **What happened?** (Students should note that the sound or picture quality of the tape has been reduced significantly because of its exposure to the magnet.)

Point out that magnetism caused the changes in the magnetic tape and that students will learn more about things like this and the relationship between magnetism and electricity in this chapter.

#### People Have the Power

Contact your local electric company and ask the public relations department to send a representative to speak to your class. (Most utility companies have such representatives and programs.) Before the representative arrives, have the students develop a list of questions that they might like to ask the representative. Sample questions might include these:

• Where does electricity come from?
• How is electricity created?
• What is done with excess electricity that is generated but not used?
• How do devices use electricity?

Have the representative make a special effort to emphasize the relationship of electricity and magnetism. Point out to students that this information will help them in their study of generators, transformers, and the relationship between magnetism and electric current.

**CHAPTER 3**

# *Electromagnetism*

## INTEGRATING SCIENCE

This physical science chapter provides you with numerous opportunities to integrate other areas of science, as well as other disciplines, into your curriculum. Blue numbered annotations on the student page and integration notes on the teacher wraparound pages alert you to areas of possible integration.

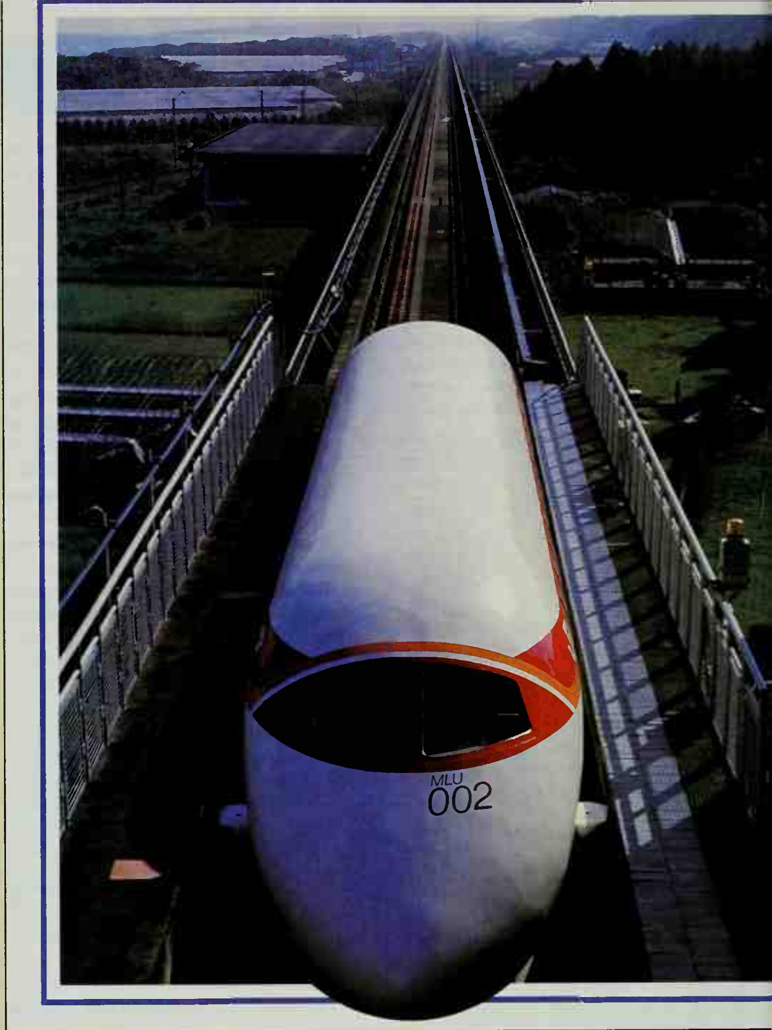
In this chapter you can integrate social studies (pp. 66, 72), language arts (p. 74), physical science and hydroelectric power (p. 75), physical science and hertz (p. 76), earth science and seismology (p. 78), and life science and electron microscopes (p. 81).

## SCIENCE, TECHNOLOGY, AND SOCIETY/COOPERATIVE LEARNING

We are surrounded by electromagnetic fields. These fields are invisible forces produced by anything that is electrical—computers, TVs, blenders, microwaves, radios, hair dryers, and many more devices that we would not want to live without. Some people are concerned that dangerous doses of electromagnetic radiation from electrical devices may cause cancer and other types of illnesses. Others say that their fears are unfounded because the electromagnetic radiation generated by electrical devices is weaker than the Earth's magnetic field and the natural electrical activity of the human body.

Evidence from a number of studies suggests that workers in electrical industries develop cancer at higher than normal rates after prolonged exposure to electromagnetic fields. Although inconclusive, this evidence has created some public concern because electromagnetic fields are found everywhere—home, the shopping mall, and even outdoors. This concern has also led to protests over power-line construction and personal-injury lawsuits.

If electromagnetic fields are found to cause cancer, America will have to be rewired! Billions of dollars will have to be spent in redesigning electric power facilities, appliances, and office equipment.




## INTRODUCING CHAPTER 3

### DISCOVERY LEARNING

▶ *Activity Book*

Begin teaching the chapter by using the Chapter 3 Discovery Activity from the *Activity Book.* Using this activity, students will explore how an electric motor works.

### USING THE TEXTBOOK

Have students observe the picture on page P64 and read its caption.

• **Describe the picture.** (Students should describe a train that travels without touching tracks.)

Have students read the chapter introduction on page P65.

• **Describe a maglev train.** (A train using electricity and magnetism would move at speeds of about 500 km/hr without touching its tracks.)

# Electromagnetism

# 3

## Guide for Reading

*After you read the following sections you will be able to*

**3–1 Magnetism From Electricity**

- Describe how a magnetic field is created by an electric current.
- Discuss the force exerted on an electric current by a magnetic field.
- Apply the principles of electromagnetism to devices such as the electric motor.

**3–2 Electricity From Magnetism**

- Explain how electricity can be produced from magnetism.
- Apply the principle of induction to generators and transformers.

Traveling by train can be convenient. But by today's standards, a long train ride can also be time-consuming. The speed of modern trains is limited by the problems associated with the movement of wheels on a track. Engineers all over the world, however, are now involved in the development of trains that "float" above the track. The trains are called maglev trains, which stands for magnetic levitation. Because a maglev train has no wheels, it appears to levitate. While a conventional train has a maximum speed of about 300 kilometers per hour, a maglev train is capable of attaining speeds of nearly 500 kilometers per hour.

Although this may seem to be some sort of magic, it is actually the application of basic principles of electricity and magnetism. Maglev trains are supported and propelled by the interaction of magnets located on the train body and on the track.

In this chapter, you will learn about the intricate and useful relationship between electricity and magnetism. And you will gain an understanding of how magnets can power a train floating above the ground.

### Journal *Activity*

***You and Your World*** Have you ever wondered where the electricity you use in your home comes from? In your journal, describe the wires you see connected across poles to all the buildings in your area. If you cannot see them, explain where they must be. Describe some of the factors you think would be involved in providing electricity to an entire city.

*A maglev train travels at high speeds without even touching its tracks*



**Cooperative learning:** Using preassigned lab groups or randomly selected teams, have groups complete one of the following assignments:

- Design a warning symbol for home appliances that can be used to make consumers aware of the possible danger of electromagnetic fields.
- Using their collective imagination and knowledge of electromagnetism, have each group design a useful electromagnetic device. Each group should provide a diagram of their device and an explanation of its function and how it works.

See Cooperative Learning in the *Teacher's Desk Reference.*

## JOURNAL ACTIVITY

You may want to use the Journal Activity as the basis of a class discussion. As students think about electricity, ask them to describe the electricity brought to and used in places like their homes, school, and the business areas of their community. Remind students to provide specific details that support their written description. Students should be instructed to keep their Journal Activity in their portfolio.

- **List one advantage of a maglev train.** (Answers will vary. Students might suggest that it is much faster than other trains.)
- **Will the maglev train pollute our atmosphere?** (No.)
- **Do you think a maglev train would provide a smooth or a bumpy ride? Why?** (Smooth. It has physical contact only with air.)
- **What kind of "fuel" is required by a maglev train?** (Electricity.)
- **List one disadvantage of a maglev train.** (Answers will vary. Students might suggest that there currently is no existing track that would be used for such trains.)
- **Where do you think we could build "tracks" for maglev trains?** (Accept logical responses. Students might suggest above existing interstate highways.)
- **Do you think a maglev train would make noise?** (Most students might suggest that it would not make noise.)

Point out that a maglev would displace air quickly because of its very fast speed. It would make noise—perhaps some sort of a "swoosh" sound.

# 3-1 Magnetism From Electricity

## MULTICULTURAL OPPORTUNITY 3-1

Have your students do a survey around their homes of all the devices that they can find that use electrical motors. When the students return to class, make a large chart of all the applications of motors to their lives. What are all the different ways in which motors are used?

## ESL STRATEGY 3-1

Have students make illustrations of a solenoid and an electromagnet, labeling their respective components and magnetic fields. To help explain the drawings, have students complete the following definitions:

A coiled wire, known as a solenoid, acts like a ______ when current flows through it.

A(n) ______ ______ is a solenoid with a core of iron.

The Intruder: Have students write the definitions of each of the following terms and select the word that does not belong in the group, stating why it should be considered misplaced.

- armature, commutator, galvanometer, electric motor

**Guide for Reading**

*Focus on this question as you read.*

- *What is the relationship between an electric current and a magnetic field?*

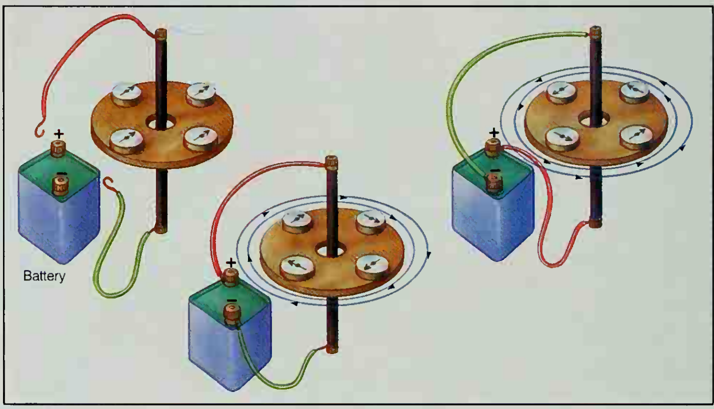
# 3–1 Magnetism From Electricity

When you think of a source of magnetism, you may envision a bar magnet or a horseshoe magnet. After reading Chapter 2, you may even suggest the Earth or the sun. But would it surprise you to learn that a wire carrying current is also a source of magnetism?

You can prove this to yourself by performing a simple experiment. Bring a compass near a wire carrying an electric current. The best place to hold the compass is just above or below the wire, with its needle parallel to it. Observe what happens to the compass needle when electricity is flowing through the wire and when it is not. What do you observe?

This experiment is similar to one performed more than 150 years ago by the Danish physicist Hans Christian Oersted. His experiment led to an important scientific discovery about the relationship between electricity and magnetism, otherwise known as **electromagnetism.**

**Figure 3–1** *A current flowing through a wire creates a magnetic field. This can be seen by the deflection of the compasses around the wire. Notice that the magnetic field is in a circle around the wire. What determines the direction of the magnetic lines of force?* 2




## TEACHING STRATEGY 3-1

### FOCUS/MOTIVATION

Illustrate Oersted's experiment by connecting copper wires and a switch to the terminals of a low-voltage dry cell, creating an open circuit. You may also choose to insert a low-voltage lamp (in series) into the circuit, providing additional evidence to students that current is flowing when the circuit is closed. Place a compass directly above or below (and close to) a wire of the circuit, orienting the wire so that the compass needle is parallel to it. Ask:

- **What do you think will happen when the switch is thrown closing the circuit and a current begins to flow through the circuit?** (Most students, before reading about Oersted's experiment, might expect that nothing will happen, either because they do not expect a magnetic force to be produced or because they expect that if such a force is produced, it will be directed parallel to the wire and thus will tend to keep the compass needle in parallel alignment. Actually, closing the circuit creates a magnetic force, and the needle of the compass will be deflected and therefore no longer parallel to the direction of the wire.)

Close and open the circuit several times. Ask students to observe the compass while the circuit is being opened and closed.

- **What did you observe?** (Students should observe the compass needle deflecting from and to its original position.)
- **How can you explain what has happened?** (Current flowing through the wire created a magnetic field that was not present when current was not present in the circuit. This magnetic field in turn

## Oersted's Discovery

For many years, Oersted had believed that a connection between electricity and magnetism had to exist, but he could not find it experimentally. In 1820, however, he finally obtained his evidence. Oersted observed that when a compass is placed near an electric wire, the compass needle deflects, or moves, as soon as current flows through the wire. When the direction of the current is reversed, the needle moves in the opposite direction. When no electricity flows through the wire, the compass needle remains stationary. Since a compass needle is deflected only by a magnetic field, Oersted concluded that an electric current produces a magnetic field. **An electric current flowing through a wire gives rise to a magnetic field whose direction depends on the direction of the current.** The magnetic field lines produced by a current in a straight wire are in the shape of circles with the wire at their center. See Figure 3–1.

## Electromagnets

Oersted then realized that if a wire carrying current is twisted into loops, or coiled, the magnetic fields produced by each loop add together. The result is a strong magnetic field in the center and at the two ends, which act like the poles of a magnet. A long coil of wire with many loops is called a **solenoid.** Thus a solenoid acts as a magnet when a current passes through it. The north and the south poles change with the direction of the current.

The magnetic field of a solenoid can be strengthened by increasing the number of coils or the amount of current flowing through the wire. The greatest increase in the strength of the magnetic field, however, is produced by placing a piece of iron in the center of the solenoid. The magnetic field of the solenoid magnetizes—or aligns the magnetic domains of—the iron. The resulting magnetic field is the magnetic field of the wire plus the magnetic field of the iron. This can be hundreds or thousands of times greater than the strength of the field produced by the wire alone. A solenoid with a magnetic material such as iron inside it is called an **electromagnet.**

### FIND OUT BY DOING

*Making an Electromagnet*

Obtain a low-voltage dry cell, nail, and length of thin insulated wire.

**1.** Remove the insulation from the ends of the wire.

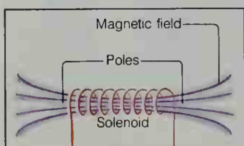
**2.** Wind the wire tightly around the nail so that you have at least 25 turns.

**3.** Connect each uninsulated end of the wire to a post on the dry cell.

**4.** Collect some lightweight metal objects. Touch the nail to each one. What happens?

■ Explain why the device you constructed behaves as it does.

**Figure 3–2** *A coil of wire carrying current is a solenoid. As a wire is wound into a solenoid, the magnetic field created by the current becomes strongest at the ends and constant in the center, like that of a bar magnet.*






### ANNOTATION KEY

**Answers**

1 The needle is deflected by the magnetic field generated when current flows through the wire. When there is no current present, the compass needle is not deflected. (Relating cause and effect)

2 The direction of the current. (Relating concepts)

**Integration**

1 Social Studies

### FIND OUT BY DOING

MAKING AN ELECTROMAGNET

**Discovery Learning**

***Skills: Making observations, applying concepts***

***Materials: low-voltage dry cell, nail, length of thin, insulated wire***

Students build a simple electromagnet in this activity and then determine which objects the electromagnet will or will not pick up. The dry cell emits an electromagnetic force that attracts the metal objects.

### ENRICHMENT

Students might be interested to learn that Oersted made his discovery while lecturing a physics class. During the lecture, he noticed a wire lying above a compass, and he observed that when current flowed through the wire, the compass needle was deflected about 90 degrees. When the direction of the current was reversed, the needle moved 90 degrees in the opposite direction. When no electricity flowed through the wire, the compass needle remained stationary. For many years, Oersted had believed that electricity and magnetism were related, and he finally found evidence of this relationship.

deflected the compass needle so that it no longer was parallel to the wire.)

### CONTENT DEVELOPMENT

Review the concept of electric current by reminding students that current is a measure of the flow rate of electrons. Have them recall that in a circuit, the flow of electrons is directional, flowing or moving away from a negative terminal toward a positive terminal. Have a volunteer draw a diagram on the chalkboard illustrating this fact. As you explain Oersted's experiment, use the chalkboard to illustrate that magnetic-field lines of force flow around the current-carrying wire, causing objects such as compass needles to align with these forces.

**• • • • Integration • • • •**

Use the experiment performed by the Danish physicist Oersted to integrate social studies concepts into your lesson.

## BACKGROUND INFORMATION

### MAGNETIC LINES OF FORCE

The direction of the lines of force of a magnetic field produced by a current can be predicted by means of the "left-hand rule." If the thumb of the left hand points in the direction of the flow of electrons, the fingers curl in the direction of the magnetic field. This rule is more conventionally stated as the "right-hand rule," in which the thumb of the right hand points in the direction of flow of current, the extended fingers point in the direction of the magnetic field, and the direction of force is on a line perpendicular to the plane of the palm.

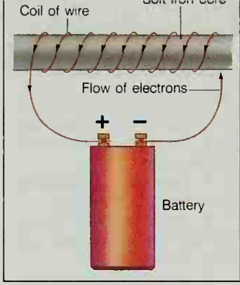



**Figure 3–3** *An electromagnet is produced when a piece of soft iron is placed in the center of a solenoid. Large electromagnets can be used to pick up heavy pieces of metal. What factors determine the strength of an electromagnet?* 2

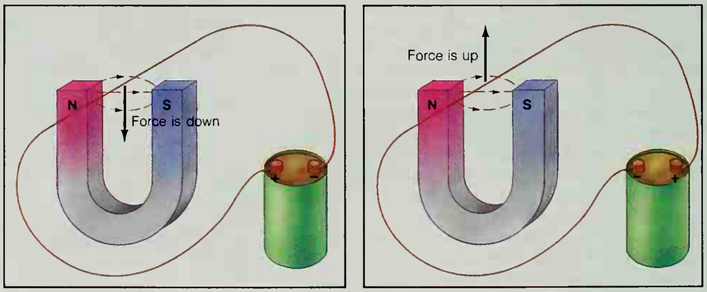
The type of iron used in electromagnets acquires and loses its magnetism when the electric current is turned on and off. This makes electromagnets strong, temporary magnets. Can you think of other ways in which this property of an electromagnet might be useful? 1

## Magnetic Forces on Electric Currents

You have just learned that an electric current exerts a force on a magnet such as a compass. But forces always occur in pairs. Does a magnetic field exert a force on an electric current?

To answer this question, consider the following experiment. A wire is placed in the magnetic field between the poles of a horseshoe magnet. When a current is sent through the wire, the wire jumps up as shown in Figure 3–4. When the direction of the

**Figure 3–4** *A magnetic field will exert a force on a wire carrying current. On what does the direction of the force depend?* 3






## 3–1 (continued)

### GUIDED PRACTICE

#### Skills Development

***Skills: Applying concepts, making observations***

You may wish to construct a simple electromagnet, wrapping a length of soft iron with many loops of insulated copper wire and connecting the ends of the wires to a low-voltage dry cell. Include a switch in the circuit. Scatter iron filings or small paper clips very near to the iron core and then close the circuit. Open and close the circuit several times. Ask students to write, without conferring, what they have observed. Also ask them to propose an explanation for what has occurred. They can then be asked to read aloud and discuss what they have written.

### CONTENT DEVELOPMENT

Point out that a number of applications, or practical devices, can be built because a magnetic field exerts a force on a wire that is carrying current. The most practical of these applications is probably the electric motor. An electric motor is a device that converts electrical energy into a more useful type of energy called mechanical energy.

Explain that a simple electric motor consists of a wire coil that is placed into a permanent magnetic field. When a current is applied into the wire coil, the magnetic field produced by the coil interacts with the permanent magnetic field. The interaction of these magnetic fields produces a force that is great enough to rotate the coil.

Stress to students that this is an explacurrent is reversed, the wire is pulled down. So the answer is yes. **A magnetic field exerts a force on a wire carrying current.** Actually, this fact should not surprise you. After all, as you learned in Chapter 2, a magnetic field can exert a force on a charged particle. An electric current is simply a collection of moving charges.

## Applications of Electromagnetism

A number of practical devices use solenoids and electromagnets because they can move mechanical parts quickly and accurately.

**ELECTRIC MOTOR** An **electric motor** is a device that changes electric energy into mechanical energy that is used to do work. (Mechanical energy is energy related to motion.) An electric motor contains an electromagnet that is free to rotate on a shaft and a permanent magnet that is held in a fixed position. The electromagnet that is free to rotate is called the armature. The armature rotates between the poles of the permanent magnet.

When a current flows through the coil of wire, the ends of the electromagnet become magnetic poles. (Recall that an electromagnet acts as a magnet whose poles depend on the direction of the current.) Because the poles of the armature are next to the same poles on the fixed magnet, they are repelled. The armature begins to rotate toward the opposite poles. But just before the armature reaches the poles, the current through the wire changes direction. This causes the poles of the armature to switch. Once again the poles of the armature and the poles of the fixed magnet repel. So the armature continues to rotate. This process occurs over and over, keeping the armature in continuous rotation.

A current that switches direction every time the armature turns halfway is essential to the operation of an electric motor. The easiest way to supply a changing current is to use AC, or alternating current, to run an electric motor. Recall that alternating current is constantly changing direction.

An electric motor can be made to run on DC, or direct current, by using a reversing switch known as a commutator. A commutator is attached to the

### FIND OUT BY DOING

*Changing Direction*

Obtain a dry cell, a compass, and a length of thin insulated wire.

**1.** Remove the insulation from both ends of the wire.

**2.** Place the compass flat on the table. Observe the direction of the needle.

**3.** Connect each uninsulated end of the wire to a post on the dry cell. Put the center of the wire across the compass. Observe the needle.

**4.** Disconnect the wires and reconnect them to the opposite terminals without moving the wire over the compass. What happens? Repeat this procedure.

■ How is the magnetic field produced by an electric current related to the direction of the current?

**Figure 3–5** *A motor can be found within most practical devices.*



### ANNOTATION KEY

Answers

1. Picking up objects to be moved from place to place, such as iron scrap in a scrap yard. (Inferring)
2. The number of coils and the amount of current in the wire. (Relating concepts)
3. The direction of the current. (Relating concepts)

### FIND OUT BY DOING

CHANGING DIRECTION

**Discovery Learning**

***Skills: Making observations, relating concepts***

***Materials: low-voltage dry cell, compass, thin, insulated wire***

In this activity students will discover that the compass needle deflects 90 degrees when current is applied to the circuit. When the direction of the current is reversed by switching wires, the compass needle deflects 90 degrees in the opposite direction.

nation of a very simple motor. Most motors are somewhat more sophisticated. In motors like those used to run a fan, for example, a current that switches direction frequently is used to switch the direction of the magnetic field. This allows the electromagnet (also called the coil or armature) to rotate continuously.

If possible, obtain a discarded or nonworking electric motor. These may be available at small businesses that specialize in repairing or rebuilding electric motors. Allow students time to disassemble the motor and examine its contents. Before the individual pieces are discarded, you might wish to save the permanent magnet and armature windings for use in future classroom demonstrations.

### ENRICHMENT

Relate the operations of the electric motor to the law of conservation of energy. Point out that some of the electrical energy is converted in a device such as a motor into mechanical energy, or energy of motion, which can then be used to do work. Explain that the remainder of the electrical energy is converted into heat energy, which in most cases is not useful for doing work. Stress to students that the total energy before the conversion is equal to the total energy after the conversion.

## INTEGRATION

### MATHEMATICS

The strength of an electromagnet can be determined using the formula

$$\text{mmf} = 1.25 \times I \times N$$

where mmf is the magnetomotive force (in gilberts), I is the current (in amperes), and N is the number of turns in the coil.

The strength of any electromagnet depends on the amount of current and the number of amperes. For example, an electromagnet with 50 turns and 2 amperes of current is equal in strength to an electromagnet with 10 turns and 10 amperes.

Have interested students use the formula to determine the strength of the electromagnets used in this chapter.

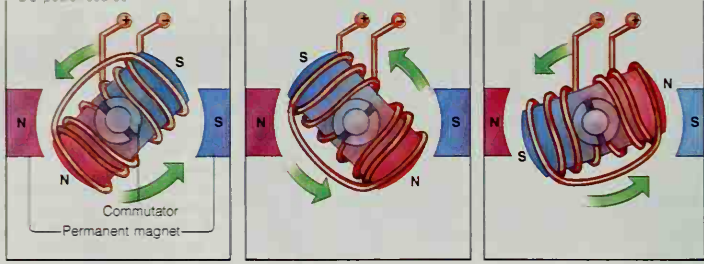
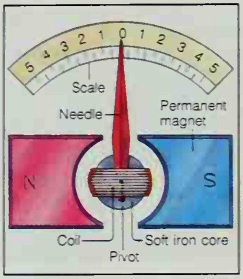



**Figure 3–6** *When alternating current flows through the wire in a motor, the poles of the movable electromagnet are reversed. The alternating attraction and repulsion between this electromagnet and a stationary magnet cause the movable electromagnet to spin on its shaft. Thus electric energy is converted into mechanical energy.*

movable electromagnet (or armature). As the electromagnet turns, the commutator switches the direction of current so that the magnetic poles of the electromagnet reverse and the electromagnet spins. Electric current is supplied to the commutator through contacts called brushes. The brushes do not move; they simply touch the commutator as it spins.

The mechanical energy of the spinning armature turns the shaft of the motor, enabling the motor to do work. The shaft can be connected to pulleys, fan blades, wheels, or almost any other device that uses mechanical energy. Sewing machines, refrigerators, vacuum cleaners, power saws, subway trains, and most industrial machinery are a few of the many devices that would be practically impossible to design without electric motors.

**Figure 3–7** *As current flows through the wire in a galvanometer, the magnet forces the wire to turn and deflect the needle attached to it. The greater the current, the greater the deflection.*




GALVANOMETER Another instrument that depends on electromagnetism is a **galvanometer.** A galvanometer is an instrument used to detect small currents. It is the basic component of many meters, including the ammeter and voltmeter you read about in Chapter 1. A galvanometer consists of a coil of wire connected to an electric circuit and a needle. The wire is suspended in the magnetic field of a permanent magnet. When current flows through the wire, the magnetic field exerts a force on the wire, causing it to move the needle of the galvanometer. The size of the current will determine the amount of force on the wire, and the amount the needle will



## 3–1 (continued)

### CONTENT DEVELOPMENT

Explain that most electric motors work the same way: A permanent magnetic field is used to rotate a coil, which carries current. Point out, however, that the strength of a motor must change according to its application. Motors that are used in children's toys, for example, usually rely on a small permanent magnet and may have coils that contain fewer than 100 turns. Large industrial motors require strong magnetic fields and consequently use very powerful electromagnets that are powered by electricity. They also may have coils that contain thousands of turns.

Regardless of the size of a motor, the principle of small motors and large motors remains the same except for their different sources of magnetic fields and size of coil windings.

### GUIDED PRACTICE

**Skills Development**

***Skills: Relating concepts, making comparisons***

At this point have students complete the in-text Chapter 3 Laboratory Investigation: Electromagnetism. In this investigation students will explore factors that may affect the strength of an electromagnet and the materials that might be attracted to it.

### ENRICHMENT

Remind students that the mechanical energy of a spinning armature turns a shaft in an electric motor, enabling the motor to do work. This shaft can be connected to pulleys, wheels, or blades.

Have a volunteer go to the chalkboard and create a list of 20 devices volunteered by other students that would be almost impossible to design without electromagnetic or electric motors.

### INDEPENDENT PRACTICE

**Section Review 3–1**

1. Both magnetism and electricity involve the movement of electrons. An electric current flowing through a wire gives rise to a magnetic field whose di-

move. Because the needle will move in the opposite direction when the current is reversed, a galvanometer can be used to measure the direction of current as well as the amount.

**OTHER COMMON USES** A simple type of electromagnet consists of a solenoid in which an iron rod is only partially inserted. Many doorbells operate with this type of device. See Figure 3–8. When the doorbell is pushed, the circuit is closed and current flows through the solenoid. The current causes the solenoid to exert a magnetic force. The magnetic force pulls the iron into the solenoid until it strikes a bell.

The same basic principle is used in the starter of an automobile. When the ignition key is turned, a circuit is closed, causing an iron rod to be pulled into a solenoid located in the car's starter. The movement of the iron rod connects the starter to other parts of the engine and moves a gear that enables the engine to turn on. Another example of the application of this principle can be found in a washing machine. The valves that control the flow of water into the machine are opened and closed by the action of an iron rod moving into a solenoid.

Some other uses of electromagnets include telephones, telegraphs, and switches in devices such as tape recorders. Electromagnets also are important in heavy machinery that is used to move materials, such as moving scrap metal from one place to another.

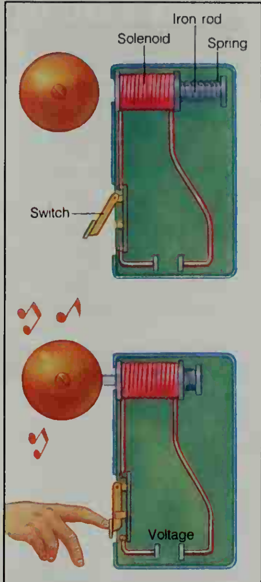



**Figure 3–8** *Whenever you ring a doorbell, you are using a solenoid. When the button is pushed, current flows through the wire causing the solenoid to act as a magnet. Once magnetic, the solenoid attracts the bar of iron until the iron strikes the bell, which then rings.*

## 3–1 Section Review

1. How is magnetism related to electricity?
2. What is an electromagnet? What are some uses of electromagnets?
3. How is an electromagnet different from a permanent magnet?
4. How does an electromagnet change electric energy to mechanical energy in an electric motor?

**Critical Thinking—*Making Comparisons***

5. How is the effect of an electric current on a compass needle different from the effect of the Earth's magnetic field on a compass needle?



## FACTS AND FIGURES

### ELECTROMAGNET NORTH AND SOUTH

The north and south pole of an electromagnet can be determined by observing the needle of a compass when it is in the vicinity of each end of the coil. The north pole of an electromagnet will repel the north pole of a compass needle, and the south pole of an electromagnet will attract the north pole of the compass needle, and vice versa.

rection depends on the direction of the current.
2. An electromagnet is produced when an electric current is passed through a coil of wire with a magnetic material such as iron inside it; depending on the amount of current and number of coil windings, electromagnets are usually very strong and are used to lift heavy pieces of metal.
3. An electromagnet can be made stronger or weaker; it can be made to lose its magnetic properties entirely by turning it off; and its poles can be reversed. The properties of a permanent magnet are constant except that its strength decreases naturally through time and use.
4. As alternating current is passed through the electromagnet, its north and south poles continuously reverse. The electromagnet is alternately attracted to and repelled by the exterior permanent magnet in the motor. This continual attraction and repulsion causes the electromagnet to spin. The mechanical energy of the spin is used to turn a shaft to do work.
5. The Earth's magnetic field will always cause a compass needle to point toward the same direction—north. An electric current will cause a compass needle to point in a direction that is dependent on the direction of the current.

### REINFORCEMENT/RETEACHING

Monitor students' responses to the Section Review questions. If students appear to have difficulty with any of the questions, review the appropriate material in the section.

### CLOSURE

▶ *Review and Reinforcement Guide*

At this point have students complete Section 3–1 in the *Review and Reinforcement Guide.*

# 3-2 Electricity From Magnetism

MULTICULTURAL OPPORTUNITY 3-2

Persons who live in rural areas of the world may not have access to electric power were it not for hydroelectric generators. Have your students research the work of the Tennessee Valley Authority, which brought power to persons living in the Appalachian Mountain area.

ESL STRATEGY 3-2

Have students write a short paragraph comparing Oersted's investigation of magnetism and electricity with Joseph Henry's related discovery. Also, have them explain why Michael Faraday's work on this subject is better known than Joseph Henry's.

Ask students to give the antonyms (words that are opposite in meaning) of *generator* and *set-up transformer.* Have them define all four terms.

**Guide for Reading**

*Focus on this question as you read.*

▶ *How does magnetism produce electricity?*

## 3–2 Electricity From Magnetism

If magnetism can be produced from electricity, can electricity be produced from magnetism? Scientists who learned of Oersted's discovery asked this very question. In 1831, the English scientist Michael Faraday and the American scientist Joseph Henry independently provided the answer. It is interesting to note that historically Henry was the first to make the discovery. But because Faraday published his results first and investigated the subject in more detail, his work is better known. 1

### Electromagnetic Induction

In his attempt to produce an electric current from a magnetic field, Faraday used an apparatus similar to the one shown in Figure 3–9. The coil of wire on the left is connected to a battery. When current flows through the wire, a magnetic field is produced. The strength of the magnetic field is increased by the iron, as in an electromagnet. Faraday hoped that the steady current would produce a magnetic field strong enough to create a current in the wire on the right. But no matter how strong the current he used, Faraday could not achieve his

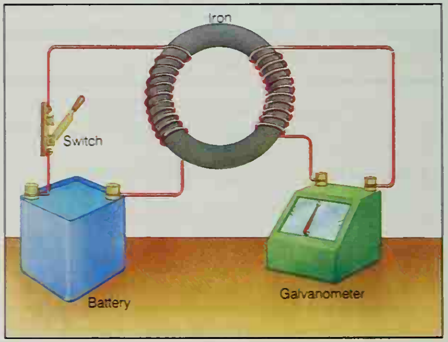



**Figure 3–9** *Using this setup, Faraday found that whenever the current in the wire on the left changed, a current was induced in the wire on the right. The changing current produced a changing magnetic field, which in turn gave rise to a current.*



### TEACHING STRATEGY 3-2

#### FOCUS/MOTIVATION

Before introducing students to the principles associated with electromagnetic induction, demonstrate Faraday's and Henry's experiments. Twist copper wire to produce a number of loops large enough to allow a bar magnet to move within the helix formed by the loops. Ask:

• **What will happen if a bar magnet is placed in the space within the loops of this copper wire?** (Answers will vary. Actually nothing will happen unless the magnet or wire is moving.)

Place the magnet within the loops and set the device down. Attach the ends of the copper-coil wires to the posts of a galvanometer. Without allowing students to see the galvanometer reading, ask:

• **How much current will be produced in this scenario?** (No current will be produced. Allow a volunteer to check the galvanometer reading, or display it to the class.)

• **What will happen if the magnet or the wire is moved?** (A current will result, though most students will not expect this, especially if you have made it a point to mention that there is no dry cell or other power source in the circuit.)

Move the magnet and then move the copper-wire loops. Have students note the galvanometer results—a current will be produced in the wire.

• **Why do you think this happens?** (Accept all logical inferences. Students might infer that the motion of the magnet is causing the wire to intersect invisible magnetic lines of force, causing electrons to flow in the wire.)

#### CONTENT DEVELOPMENT

Introduce the topic of electromagnetic induction by reminding students that magnetism and electricity are redesired results. The magnetic field did not produce a current in the second wire. However, something rather strange caught Faraday's attention. The needle of the galvanometer deflected whenever the current was turned on or off. Thus a current was produced in the wire on the right, but only when the current (and thus the magnetic field) was changing.

Faraday concluded that although a steady magnetic field produced no electric current, a changing magnetic field did. Such a current is called an **induced current.** The process by which a current is produced by a changing magnetic field is called **electromagnetic induction.**

Faraday did many other experiments into the nature of electromagnetic induction. In one, he tried moving a magnet near a closed loop of wire. What he found out was that when the magnet is held still, there is no current in the wire. But when the magnet is moved, a current is induced in the wire. The direction of the current depends on the direction of movement of the magnet. In another experiment he tried holding the magnet still while moving the wire circuit. In this case, a current is again induced.

The one common element in all Faraday's experiments is a changing magnetic field. It does not matter whether the magnetic field changes because the magnet moves, the circuit moves, or the current

## FIND OUT BY DOING

*Compass Interference*

Use a compass to explore the magnetic properties of a room. Take the compass to different parts of the room to see which way the needle points. Can you find places where the compass does not point north? Why does it point in different directions?

■ What precautions must a ship's navigator take when using a compass?

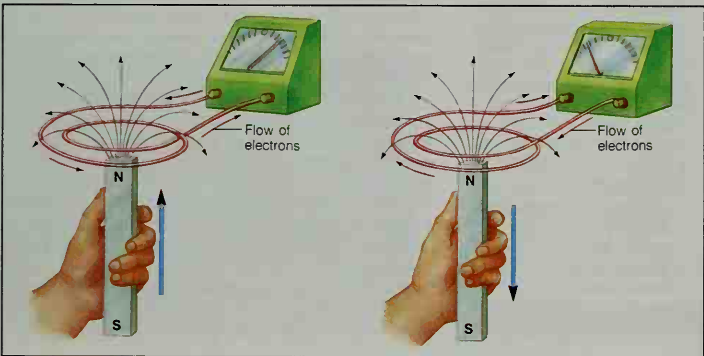



**Figure 3–10** *A current is induced in a wire that is exposed to a changing magnetic field. Here the magnet is moved past a stationary wire. On what does the direction of the current depend?* ❶

### ANNOTATION KEY

**Answers**

❶ The direction of the moving magnet. (Interpreting illustrations)

**Integration**

❶ Social Studies

### FIND OUT BY DOING

COMPASS INTERFERENCE

**Discovery Learning**

***Skills: Making observations, relating cause and effect***

***Material: compass***

This activity allows students to relate magnetic influences to their environment. Students should discover that there are places within the classroom environment at which the compass does not point true magnetic north, and they should conclude that the proximity of metallic objects influences the compass. Students should infer that a ship's navigator using a magnetic compass should use the compass at places on the ship that are located as far away as possible from the influence of metallic objects.

lated. Have students recall that Oersted's experiments showed that magnetism can be produced by an electric current that involves a changing electric field. Stress that the electric field is now changing. Because this connection or relationship exists between electricity and magnetism, suggest that it should not be too surprising if an electric current could be produced from a changing magnetic field. Faraday's and Henry's experiments showed that such production does occur.

**• • • • Integration • • • •**

Use the work of Michael Faraday and Joseph Henry to integrate social studies concepts into your science lesson.

**ENRICHMENT**

Point out that symmetries, such as an electric current being produced from a changing magnetic field (or conversion of mechanical energy into heat energy, suggesting the possible conversion of heat energy into mechanical energy), are common in science. Many theoretical scientists expect these symmetries and, as a result, often hypothesize their existence before finding experimental evidence in support of them. Such examples help to bring out what are sometimes called aesthetic considerations (beliefs in the symmetry, beauty, and underlying simplicity and unity of nature), which play a major role in the creation of new and important hypotheses and theories.

## FIND OUT BY WRITING

THE HISTORY OF ELECTROMAGNETISM

Completing this activity will help students obtain background information about many important scientists who contributed to the discovery of electricity and its many applications. Check students' reports for historical and scientific accuracy.

**Integration:** Use the Find Out by Writing activity to integrate language arts skills into your science lesson.

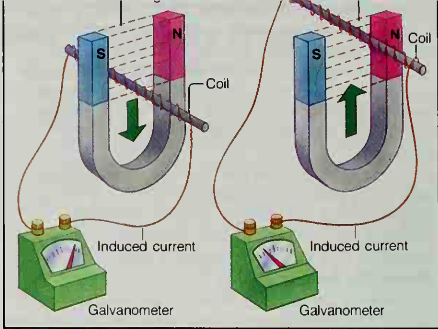



**Figure 3-11** *A current is also induced in a wire when the wire is moved through a stationary magnetic field.*

giving rise to the magnetic field changes. It matters only that a changing magnetic field is experienced. **An electric current will be induced in a circuit exposed to a changing magnetic field.**

It may help you to think about electromagnetic induction in terms of magnetic lines of force. In each case magnetic lines of force are being cut by a wire. When a conducting wire cuts across magnetic lines of force, a current is produced.

**GENERATORS** An important application of electromagnetic induction is a **generator.** A generator is a device that converts mechanical energy into electrical energy. How does this energy conversion compare with that in an electric motor? Generators in power plants are responsible for producing about 99 percent of the electricity used in the United States.

A simple generator consists of a loop of wire mounted on a rod, or axle, that can rotate. The loop of wire, which is attached to a power source, is placed between the poles of a magnet. When the loop of wire is rotated by the power source, it moves through the field of the magnet. Thus it experiences a changing magnetic field (magnetic lines of force are being cut). The result is an induced current in the wire.

As the loop of wire continues to rotate, the wire moves parallel to the magnetic lines of force. At this point the field is not changing and no lines of force

### FIND OUT BY WRITING

*The History of Electromagnetism*

1 Several scientists were responsible for establishing the relationship between electricity and magnetism. Using books and reference materials in the library, write a report about the scientists listed below. Include information about their lives as well as their contributions to a better understanding of electromagnetism.

Hans Christian Oersted
André Ampère
Michael Faraday
Joseph Henry
Nikola Tesla

74 ■ P

## 3-2 (continued)

### REINFORCEMENT/RETEACHING

▶ *Activity Book*

Students who need practice in understanding the relationship between electricity and magnetism should complete the chapter activity called Effect of a Magnet on a Television. In this activity students will observe the effect a magnet causes on the image produced by a black-and-white television. (Remind students that this activity is not to be performed using a color television, as serious damage to the television would result.)

### CONTENT DEVELOPMENT

Have students recall the principles of an electric motor—an electric motor converts electrical energy into mechanical energy. Point out that in terms of energy conversion, a generator is the opposite of an electric motor—a generator converts mechanical energy into electrical energy.

Explain that a generator is a rotatable coil of wire placed in a constant magnetic field. As the coil rotates in the magnetic field, it cuts magnetic lines of force within the field. Depending on the position of the coil at any instant, it could cut very many or very few of the lines of force. In other words, the magnetic field is changing as the coil is spinning inside it. This changing magnetic field induces current in the wire.

Point out that the current produced by a generator is alternating current, or AC. (Have students recall that direct current, or DC, consists of a one-way movement of energy.) The alternating current that has become standardized for use in the United States is 60 hertz, or 60 cycles per second.

### • • • • Integration • • • •

Use Figure 3–13 to integrate concepts of hydroelectric power into your lesson.

### INDEPENDENT PRACTICE

▶ *Multimedia* ◀

You may want to show the video Electricity and Magnetism to reinforce the

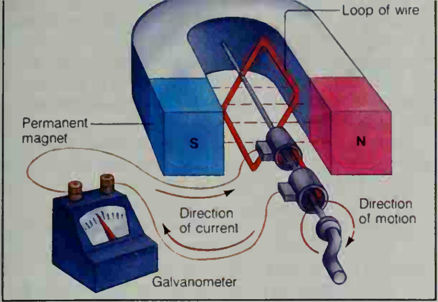



**Figure 3–12** *Inside a basic generator, a loop of wire is rotated through a stationary magnetic field. Because the wire continuously changes its direction of movement through the field, the induced current keeps reversing direction. What type of current is produced?* 1

are cut, so no current is produced. Further rotation moves the loop to a position where magnetic lines of force are cut again. But this time the lines of force are cut from the opposite direction. This means that the induced current is in the opposite direction. Because the direction of the electric current changes with each complete rotation of the wire, the current produced is AC, or alternating current.

The large generators in power plants have many loops of wire rotating inside large electromagnets. The speed of the generators is controlled very carefully. The current is also controlled so that it reverses direction 120 times each second. Because two reversals make one complete cycle of alternating

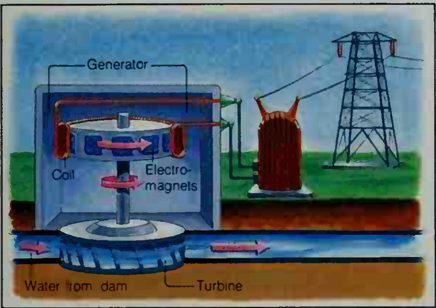



**Figure 3–13** *In the operation of a modern generator, a source of mechanical energy—such as water—spins a turbine. The turbine moves large electromagnets encased in coils of insulated wire. As the electromagnets move, the coiled wire cuts through a magnetic field, inducing an electric current in the wire.*



## ANNOTATION KEY

**Answers**

1 AC, or alternating current. (Relating concepts)

**Integration**

1 Language Arts

2 Physical Science: Hydroelectric Power. See *Ecology: Earth's Natural Resources*, Chapter 1.

## HISTORICAL NOTE

### MICHAEL FARADAY

Michael Faraday (1791–1867) is considered to be one of the greatest experimenters and theoreticians of all time. As well as discovering the principle of electromagnetic induction, he was the principal architect of the classical field theory that was later modified by James Clerk Maxwell and Albert Einstein.

Among his other accomplishments, Faraday discovered the principle of the electric motor and built a simple model of one. He also produced the first dynamo, stated the basic laws of electrolysis, and discovered that a magnetic field will rotate the plane of polarization of light.

concept of how generators produce electricity and to extend understanding of the relationship between motion, electricity, and magnetism. The video explores how the forces exerted by moving electric charges and magnets are related, how magnetic fields are concentrated to produce powerful electromagnets, and how interacting magnetic fields produce rotary motion in electric motors. After viewing the video, have students perform research concerning portable electric generators, finding out about their uses and how they provide the motion necessary to generate electricity.

### REINFORCEMENT/RETEACHING

For some students, the production and nature of alternating current may be a difficult concept to understand. For the benefit of such students, analyze carefully the structures and processes involved in alternating-current production, drawing their attention to Figure 3–11. Ask students to construct a similar model, using a wire and a horseshoe magnet, and have them demonstrate that as the wire loop is turned through a revolution, any given segment of it cuts through the lines of force first from one direction (say, up to down), then from the opposite direction (down to up). This produces differing directions of electron flow, and thus the changing or alternation of current direction.

## ECOLOGY NOTE

### HYDROELECTRIC DAMS

Every hydroelectric dam constructed has had an impact on the environment of the area in which it was built. Have interested students choose an ecosystem and a hydroelectric dam, researching the dam's environmental impact on the local and regional ecosystems. Findings should be shared with the class.

1 current, the electricity generated has a frequency of 60 hertz. (Frequency is the number of cycles per second, measured in hertz.) Alternating current in the United States has a frequency of 60 hertz. In many other countries, the frequency of alternating current is 50 hertz.

Generators can also be made to produce direct current. In fact, the system proposed and developed by Thomas Edison distributed direct-current electricity. However, the method of alternating current, developed by Edison's rival Nikola Tesla, eventually took its place. When only direct current is used, it has to be produced at high voltages, which are extremely dangerous to use in the home and office. Alternating current, however, can be adjusted to safe voltage levels.

You may wonder about what type of power source is responsible for turning the loop of wire in a generator. In certain generators it can be as simple as a hand crank. But in large generators turbines provide the mechanical energy to turn the axles. Turbines are wheels that are turned by the force of moving wind, water, or steam. Most of the power used in the United States today is generated at steam

**Figure 3–14** *The force of moving water can be used to spin turbines in generators located in a power plant such as this one at Hoover Dam. What energy conversion takes place in a generator?* 1



## 3-2 (continued)

### CONTENT DEVELOPMENT

Point out that most large power plants use sophisticated generators to create electricity. Because of the enormous size of the coils used in these generators, very large magnetic fields are required. These fields are supplied by powerful electromagnets.

In a power plant generator, the rotating coils need energy to spin, and this energy is usually provided by a turbine. A turbine is something like a fan with blades—falling water or steam causes the blades to spin or rotate, in turn causing the coil to spin within the magnetic field. If falling water is used to spin turbine blades, the large generators form part of a hydroelectric power plant. Direct students' attention to Figure 3–14. If rising steam is used to turn the turbine blades, the steam is usually provided by the burning of fossil fuels or by the heat energy released by nuclear fission.

### • • • • Integration • • • •

Use the examples of alternating current in other countries to integrate hertz concepts into your lesson.

### GUIDED PRACTICE

**Skills Development**

***Skill: Relating concepts***

Ask students to observe Figure 3–14 and examine the generators used in the power plant at Hoover Dam.

- **What is providing mechanical energy to this system?** (The water is providing the mechanical energy.)
- **How do you know that the water represents mechanical energy?** (The water is moving; as a result, it has mechanical energy.)
- **What is mechanical energy?** (It is the energy of motion.)

Have students observe Figure 3–15 and note the generator used on the bicycle.

plants. There the heat from the burning of fossil fuels (coal, oil, natural gas) or from nuclear fission boils water to produce high-pressure steam that turns the turbines. In many modern generators, the loop remains stationary, but the magnetic field rotates. The magnetic field is produced by a set of electromagnets that rotate.

If you own a bicycle that has a small generator attached to the back wheel to operate the lights, you are the source of power for the generator. To turn the lights on, a knob on the generator is moved so that it touches the wheel. As you pedal the bike, you provide the mechanical energy to turn the wheel. The wheel then turns the knob. The knob is attached to a shaft inside the generator. The shaft rotates a coil of wire through a magnetic field. What happens to the lights when you stop pedaling? 2

A small electric generator, often called an alternator, is used to recharge the battery in a car while the engine is running. Even smaller electric generators are used extensively in the conversion of information into electric signals. When you play a conventional record, for example, the grooves in the record cause the needle to wiggle. The needle is connected to a tiny magnet mounted inside a coil. As the magnet wiggles, a current is induced that corresponds to the sounds in the record grooves. This signal drives loudspeakers, which themselves use magnetic forces to convert electric signals to sound.

When you play a videotape or an audiotape, you are again taking advantage of induced currents. When information is taped onto a videotape or audiotape, it is in the form of an electric signal. The electric signal is fed to an electromagnet. The strength of the field of the electromagnet depends on the strength of the electric signal. The tape is somewhat magnetic. When it passes by the electromagnet, the magnetic field pulls on the magnetic domains of the tape. According to the electric signal, the domains are arranged in a particular way. When the recorded tape is played, a tiny current is induced due to the changing magnetic field passing the head of the tape player. The magnetic field through the tape head changes with the changing magnetic field of the tape, inducing a current that corresponds to

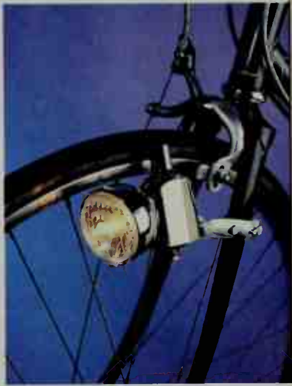


**Figure 3-15** *A light powered by a generator on a bicycle uses the mechanical energy of the spinning tire to rotate the wire. Can the light be on when the bicycle is not in use?* 3



## ANNOTATION KEY

### Answers

1 Mechanical energy into electrical energy. (Relating facts)

2 The light stops shining. (Inferring)

3 No. (Inferring)

### Integration

1 Physical Science: Hertz. See *Sound and Light*, Chapter 2.

## FACTS AND FIGURES

### MAXWELL'S EQUATIONS

In 1864, James Clerk Maxwell described the interrelationship between electricity and magnetism with a set of four famous equations known as "Maxwell's equations."

• **What is providing mechanical energy to this system?** (The person pedaling the moving bicycle is providing the mechanical energy.)

• **If you could look inside this generator, what would you expect to find?** (Because the system is a simple generator, students should expect to find a coil that rotates within a magnetic field.)

### CONTENT DEVELOPMENT

Remind students of the practical application of devices, such as generators, that create electricity using induced currents. Point out that usually the electricity used by students in school and at home is manufactured somewhere by the use of generators in a large power plant. Even if a home is powered by an alternative energy system such as a windmill, the windmill will be connected to a generator.

Also point out that another type of generator, called an alternator, powers the electrical system of an automobile. Explain to students that the electrical needs of an automobile are great by using the chalkboard to list some systems in an automobile that require electricity to operate. After these systems have been listed, ask students to decide how long all these systems would work if a car did not have a mechanical source of electricity and was powered instead by small batteries such as those used in portable radios, cameras, remote control units, and so forth. Point out that even a large battery is too small to power the electrical needs of an automobile. When an automobile is working properly, the battery is simply used to start the car. After the automobile is running and the spinning alternator is producing electricity, the electrical needs of the vehicle are met by the alternator's output—not by the battery. That is why car batteries can last for several years.

## FIND OUT BY DOING

AN ELECTRIFYING EXPERIENCE

**Discovery Learning**

***Skills: Making observations, making comparisons***

***Materials: thin insulated wire, galvanometer, strong and weak bar magnets***

This activity helps to reinforce understanding of the process of electromagnetic induction. Although the degree and direction of galvanometer deflection will vary in the activity, depending on conditions, students should explain each of their observations and discover that increasing the number of coils, increasing the strength of the magnet, increasing the speed of the magnet, and increasing the distance the magnet moves are the variables that have the greatest influences on the galvanometer.

## 3–2 (continued)

### GUIDED PRACTICE

▶ *Laboratory Manual*

**Skills Development**

***Skill: Making comparisons***

Have students complete the Chapter 3 Laboratory Investigation in the *Laboratory Manual* called Studying Electromagnetic Induction. In this investigation students will explore various magnetic conditions that create electricity.

### CONTENT DEVELOPMENT

Direct students' attention to Figure 3–16, which illustrates step-up and step-down transformers. Detail the structure and operation of each. Have students note the change in the number of loops or windings in each situation—a step-up transformer has fewer windings on the primary coil than on the secondary coil, and a step-down transformer has fewer windings on the secondary coil than on the primary coil.

### FIND OUT BY DOING

*An Electrifying Experience*

**1.** Remove the insulation from both ends of a length of thin insulated wire.

**2.** Coil the wire into at least 7 loops.

**3.** Connect each uninsulated end of the wire to a terminal of a galvanometer.

**4.** Move the end of a bar magnet halfway into the loops of the wire. Observe the galvanometer needle.

**5.** Move the magnet faster and slower. Observe the needle.

**6.** Increase and decrease the number of loops of the wire. Observe the needle.

**7.** Move the magnet farther into the loops and not as far. Observe the needle.

**8.** Use a strong bar magnet and a weak one. Observe the needle.

■ What process have you demonstrated?

■ Explain all your observations.

■ What variables affect the process the most? The least?

the information—audio, video, or computer data—recorded on the tape. Magnetic disks used for information storage in computers work on the same principle. For this reason, placing a tape next to a strong magnet or a device consisting of an electromagnet can destroy the information on the tape.

Devices that use electromagnetic induction have a wide variety of applications. In the field of geophysics, a device called a geophone, or seismometer, is 1 used to detect movements of the Earth—especially those associated with earthquakes. A geophone consists of a magnet and a coil of wire. Either the magnet or the wire is fixed to the Earth and thus moves when the Earth moves. The other part of the geophone is suspended by a spring so that it does not move. When the Earth moves, a changing magnetic field is experienced and an electric current is induced. This electric current is converted into an electric signal that can be detected and measured. Why is a geophone a valuable scientific instrument? 1

**TRANSFORMERS** A **transformer** is a device that increases or decreases the voltage of alternating current. A transformer operates on the principle that a current in one coil induces a current in another coil.

A transformer consists of two coils of insulated wire wrapped around the same iron core. One coil is called the primary coil and the other coil is called the secondary coil. When an alternating current passes through the primary coil, a magnetic field is created. The magnetic field varies as a result of the alternating current. Electromagnetic induction causes a current to flow in the secondary coil.

If the number of loops in the primary and the secondary coils is equal, the induced voltage of the secondary coil will be the same as that of the primary coil. However, if there are more loops in the secondary coil than in the primary coil, the voltage of the secondary coil will be greater. Since this type of transformer increases the voltage, it is called a step-up transformer.

In a step-down transformer, there are fewer loops in the secondary coil than there are in the primary coil. So the voltage of the secondary coil is less than that of the primary coil.

Transformers play an important role in the transmission of electricity. Power plants are often situated



### GUIDED PRACTICE

**Skills Development**

***Skill: Making comparisons***

You may wish to have students construct simple step-up and step-down transformers that are similar to those pictured in Figure 3–16.

### ● ● ● ● Integration ● ● ● ●

Use the explanation of the geophone to integrate seismology concepts into your lesson.

### CONTENT DEVELOPMENT

Because our lives are quite dependent on electricity and its transmission, highlight some of these concepts to students. Point out that long-distance transmission wires pose much resistance to the flow of

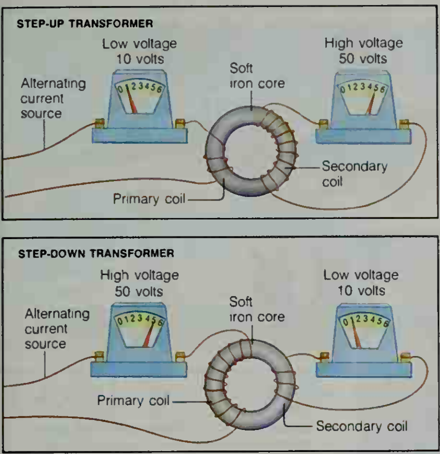



**Figure 3–16** *A transformer either increases or decreases the voltage of alternating current. A step-up transformer increases voltage. A step-down transformer decreases voltage. Which coil has the greater number of loops in each type of transformer?* 2

long distances from metropolitan areas. As electricity is transmitted over long distances, there is a loss of energy. At higher voltages and lower currents, electricity can be transmitted with less energy wasted. But if power is generated at lower voltages and also used at lower voltages, how can high-voltage transmission be achieved? By stepping up the voltage before transmission (step-up transformer) and stepping it back down before distribution (step-down transformer), power can be conserved.

Step-up transformers are used by power companies to transmit high-voltage electricity to homes and offices. They are also used in fluorescent lights and X-ray machines. In television sets, step-up transformers increase ordinary household voltage from 120 volts to 20,000 volts or more.

**Figure 3–17** *Electric current is most efficiently transmitted at high voltages. However, it is produced and used at low voltages. For this reason, electric companies use transformers such as these to adjust the voltage of electric current. Why is alternating current more practical than direct current?* 3



## ANNOTATION KEY

### Answers

1 Accept logical answers. Students might suggest that it may help to predict major earthquakes. (Inferring)

2 Step-up: secondary; step-down: primary. (Relating facts)

3 The current and voltage levels necessary for direct-current transmission are extremely high and more hazardous than those required for alternating-current transmission. (Applying concepts)

### Integration

1 Earth Science: Seismology. See *Dynamic Earth*, Chapter 2.

## BACKGROUND INFORMATION

### CHANGES IN VOLTAGE

One reason why electricity is transmitted in AC rather than DC form is that it is easy, using devices such as transformers, to change the voltage for an AC current. There is no convenient way to do this for a DC current. Because the relatively low-voltage, high-current electricity produced by generators (whose moving parts would have to turn at impractical high speeds to produce high voltage) would, in transmission through wires, heat the wires and lose energy, step-up transformers are used before the generated electricity is transmitted. This high voltage, however, turns out to be too dangerous and inconvenient for household use, so a step-down transformer is used to reduce voltage before it enters household wiring or leaves the outdoor power lines.

electricity, generating heat and causing energy to be lost. To reduce losses, currents must be kept as small as possible, and voltages must be increased significantly from the levels at which they were generated. This is accomplished by the use of step-up transformers at a power plant. The electricity traveling through the lines, however, is not able to be used until it travels through a step-down transformer near the place where it is used.

### ENRICHMENT

▶ *Activity Book*

Students will be challenged by the Chapter 3 activity in the *Activity Book* called Transformers. In this activity students will explore the relationship between the number of turns on a coil to voltage and will use this relationship to determine the primary or secondary voltage of various transformers.

## HISTORICAL NOTE

### TRANSFORMERS

Most engineers during the nineteenth century incorrectly believed that only DC electricity was useful in practical applications of electricity. As a result, early generators included inconvenient commutators, which converted (what was in reality more usable) AC into DC. Even though transformers (which could have been used in the transmission of AC current) were invented as early as 1838 by Joseph Henry, they were not used in transmission until after the usefulness of AC systems was demonstrated in Paris in 1883. American patent rights for the system, which was used in a London railway line and in Italy in 1884, were purchased by George Westinghouse, who set up the Westinghouse Electric Company. This, the first United States company to distribute alternating current, began transmitting it for lighting purposes in Buffalo, New York, in 1886.

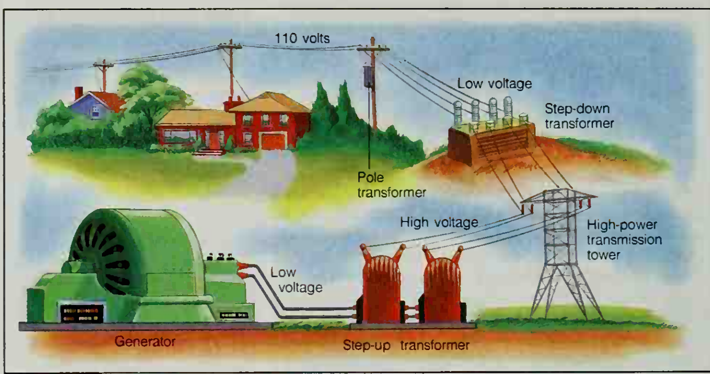



**Figure 3–18** *Low-voltage current produced at a power plant is stepped-up before being sent over long wires. Near its destination, high-voltage current is stepped-down before it is distributed to homes and other buildings. Current may be further transformed in appliances that require specific voltages.*

Step-down transformers reduce the voltage of electricity from a power plant so it can be used in the home. Step-down transformers are also used in doorbells, model electric trains, small radios, tape players, and calculators.

## 3–2 Section Review

1. What is electromagnetic induction?
2. How can an electric current be produced from a magnetic field?
3. What is the purpose of a generator?
4. What is the difference between a step-up and a step-down transformer?

**Connection—*You and Your World***

5. What are some common objects that use either electromagnetism or electromagnetic induction?

80 ■ P

## 3–2 (continued)

### CONTENT DEVELOPMENT

The relationship between the number of loops in transformer coils and voltages was expressed by Michael Faraday and is known as Faraday's law:

$$\frac{\text{Primary Voltage}}{\text{Number of Loops in Primary Coil}} = \frac{\text{Secondary Voltage}}{\text{Number of Loops in Secondary Coil}}$$

Write this formula on the chalkboard and have students determine various answers, given three of the four values in this formula.

### ENRICHMENT

Some of the many additional applications of electromagnetism include electron microscopes, certain types of spectrometers, and electromagnetic pumps. An electromagnetic pump is used in the health-care industry when blood needs to be pumped. An electromagnetic pump is favorable to a mechanical pump because a mechanical pump consists of moving parts that might cause damage to blood cells. Because of the relationship between electricity and magnetism, a pump for blood has been built that contains no moving parts. Have interested students find out more about electromagnetic pumps and other health-related applications of electricity and magnetism and share their findings with the class.

### INDEPENDENT PRACTICE

▶ *Activity Book*

Students who need practice on the concept of electromagnetic strength should be provided with the Chapter 3 activity called Electricity ↔ Magnetism. In this activity students will predict the impact of changes to a circuit and will graphically represent the strength of various electromagnets.

### ENRICHMENT

Have interested students perform library research concerning the uses of step-up and step-down transformers. Encourage these students to prepare charts

# CONNECTIONS

## Smaller Than Small ❶

When you have difficulty seeing a very small object, do you use a magnifying glass to help you? A magnifying glass enlarges the image of the object you are looking at. If you want to see an even smaller object, you may need a *microscope*. A microscope is an instrument that makes small objects appear larger. The Dutch biologist Anton van Leeuwenhoek is given credit for developing the first microscope. His invention used glass lenses to focus light.

The light microscope, which has descended from Van Leeuwenhoek's original device, still uses lenses in such a way that an object is magnified. Light microscopes are very useful. But due to the properties of light, there is a limit to the magnification light microscopes can achieve. How then can objects requiring greater magnification be seen? In the 1920s, scientists realized that a beam of electrons could be used in much the same way as light was. But microscopes that use electron beams cannot use glass lenses. Instead, they use lenses consisting of magnetic fields that exert forces on the electrons to bring them into focus. The magnetic fields are produced by electromagnets.

Electron microscopes have one major drawback. The specimens to be viewed under an electron microscope must be placed in a vacuum. This means that the specimens can no longer be alive. Despite this disadvantage, electron microscopes are extremely useful for studying small organisms, parts of organisms, or the basic structure of matter. Electron microscopes have opened up a new world!

*High-precision microscopes have enabled researchers to peer into the world of the tiny. On this scale you may hardly recognize an ant's head, the cells responsible for pneumonia, or a stylus traveling through the grooves of a record.*

ANNOTATION KEY

Integration

❶ Life Science: Electron Microscopes. See *The Nature of Science*, Chapter 3.

CONNECTIONS

SMALLER THAN SMALL

The Connections feature gives students an opportunity to relate the concepts of electricity and magnetism to the real-life use of electron microscopes. As you discuss the implications of the article, ask students why the use of an electron microscope to view only nonliving specimens is a disadvantage. Also discuss ways that the electron microscope may be able to improve the quality of our lives.

If you are teaching thematically, you may want to use the Connections feature to reinforce the themes of energy, scale and structure, systems and interactions, and stability.

**Integration:** Use the Connections feature to integrate the use of electron microscopes into your lesson.

or other illustrations that include cutaway drawings of the transformers, with labels depicting their major features. All the information gathered and created can then be presented to the class.

### INDEPENDENT PRACTICE

#### Section Review 3–2

1. Electromagnetic induction is the process by which a current is produced by the motion of a conductor in a magnetic field.
2. A current can be produced by moving a wire through a magnetic field, or a current can be produced by passing a magnet in and out of coils of wire, cutting the magnetic lines of force.
3. A generator converts mechanical energy into electrical energy.
4. A step-up transformer increases voltage and has more loops in the secondary coil than in the primary coil. A step-down transformer decreases voltage and has fewer loops in the secondary coil than in the primary coil.
5. Answers will vary. Students might suggest electric motors, telephones, and generators.

### REINFORCEMENT/RETEACHING

Review students' responses to the Section Review questions. Reteach any material that is still unclear, based on students' responses.

### CLOSURE

▶ *Review and Reinforcement Guide*

Students may now complete Section 3–2 in the *Review and Reinforcement Guide*.

# Laboratory Investigation

## ELECTROMAGNETISM

### BEFORE THE LAB

**1.** Gather all materials at least one day prior to the investigation. You should gather enough to meet your class needs, assuming six students per group.
**2.** Make certain that the dry cell is of low voltage, that the nails used are made of iron or steel, and that the wire used is insulated bell wire.
**3.** Among the "other objects to be tested," include nonmetallic as well as metallic objects.

### PRE-LAB DISCUSSION

Have students read the complete laboratory procedure.

Briefly review the basic principles of magnetism and Oersted's discovery. Then make sure the laboratory procedure is clear to students.

• **What is the purpose of this investigation?** (To determine what factors affect the strength of an electromagnet and to determine what materials are attracted to the electromagnet.)

• **Of all the objects that we will test in this investigation, which of them do you predict will be attracted to the electromagnet?** (Accept all predictions.)

### SAFTEY TIPS

Before beginning the investigation, caution students not to operate the electromagnet—that is, not to have the circuit closed with both wire ends connected to the dry-cell terminals—for more than a few seconds at a time.

# Laboratory Investigation

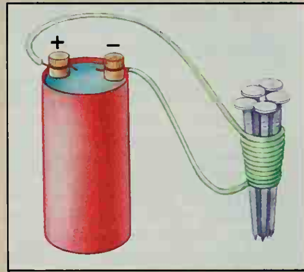
## *Electromagnetism*

### Problem

What factors affect the strength of an electromagnet? What materials are attracted to an electromagnet?

### Materials *(per group)*

| | |
|---|---|
| dry cell | nickel |
| 6 paper clips | dime |
| 5 iron nails, 10 cm long | |
| 2 meters of bell wire | |
| small piece of aluminum foil | |
| penny or copper sheet | |
| other objects to be tested | |




### Procedure

1. Hold the five nails together and neatly wrap the wire around them. Do not allow the coils to overlap. Leave about 50 cm of wire at one end and about 100 cm at the other end.
2. Attach the shorter end of the wire to one terminal of the dry cell.
3. Momentarily touch the 100-cm end of the wire to the other terminal of the dry cell. **CAUTION:** *Do not operate the electromagnet for more than a few seconds each time.*
4. When the electromagnet is on, test each material for magnetic attraction. Record your results.
5. During the time the electromagnet is on, determine the number of paper clips it can hold.
6. Wrap the 100-cm end of wire over the first winding to make a second layer. You should use about 50 cm of wire. There should be approximately 50 cm of wire remaining.
7. Connect the wire once again to the dry cell. Determine the number of paper clips the electromagnet can now hold. Record your results.
8. Carefully remove three nails from the windings. Connect the wire and determine the number of paper clips the electromagnet can hold. Record your results.
9. Determine whether the electromagnet attracts the penny, nickel, dime, and other test objects.

### Observations

What materials are attracted to the electromagnet?

### Analysis and Conclusions

1. What do the materials attracted to the magnet have in common?
2. When you increase the number of turns of wire, what effect does this have on the strength of the electromagnet?
3. How does removing the nails affect the strength of the electromagnet?
4. **On Your Own** How can you increase or decrease the strength of an electromagnet without making any changes to the wire or to the nails? Devise an experiment to test your hypothesis.



### TEACHING STRATEGY

Make sure students take enough time during the investigation to ensure that each electrical connection is mechanically sound.

### DISCOVERY STRATEGIES

Discuss how the investigation relates to the chapter by asking open questions similar to the following:

• **Based on what you studied about the properties of electromagnets, what do you think would happen if additional layers of coil windings were made on the nail?** (The electromagnet would increase strength—inferring, predicting.)

• **If a compass were present during the investigation, how could we change the direction of its deflection when the electromagnet is turned on?** (Change the direction of the current—relating, applying.)

• **Does the battery in this investigation represent alternating current or direct**

# Study Guide

## Summarizing Key Concepts

### 3–1 Magnetism From Electricity

- ▲ A magnetic field is created around a wire that is conducting electric current.
- ▲ The relationship between electricity and magnetism is called electromagnetism.
- ▲ A coiled wire, known as a solenoid, acts as a magnet when current flows through it. A solenoid with a core of iron acts as a strong magnet called an electromagnet.
- ▲ A magnetic field exerts a force on a wire conducting current.
- ▲ An electric motor converts electric energy into mechanical energy that is used to do work.
- ▲ A galvanometer is a device consisting of an electromagnet attached to a needle that can be used to measure the strength and direction of small currents.

### 3–2 Electricity From Magnetism

- ▲ During electromagnetic induction, an electric current is induced in a wire exposed to a changing magnetic field.
- ▲ One of the most important uses of electromagnetic induction is in the operation of a generator, which converts mechanical energy into electric energy.
- ▲ A transformer is a device that increases or decreases the voltage of alternating current. A step-up transformer increases voltage. A step-down transformer decreases voltage.

## Reviewing Key Terms

*Define each term in a complete sentence.*

### 3–1 Magnetism From Electricity

electromagnetism
solenoid
electromagnet
electric motor
galvanometer

### 3–2 Electricity From Magnetism

induced current
electromagnetic induction
generator
transformer



**current? Why?** (The battery represents direct current because electrons are continuously moving in the same direction through the wire—relating, comparing.)

**OBSERVATIONS**

**1.** Answers will vary, depending on materials used in the investigation.

**ANALYSIS AND CONCLUSIONS**

**1.** The materials are magnetic in nature—probably made of iron or steel.

**2.** The strength of the electromagnet is increased.

**3.** The strength of the electromagnet is decreased.

**4.** The size of the dry cell could be increased to increase the amount of current applied to the electromagnet. Experiment designs will vary. Remind students, however, to use caution when designing an experiment with unknowns, such as increasing the current of an experiment to observe what will happen, because of potential safety hazards.

**GOING FURTHER: ENRICHMENT**

**Part 1**

Interested students may wish to perform additional steps of a more quantitative nature, such as varying the number of turns of wire and making plots of the number of paper clips held versus number of turns of coil wire and battery strength.

**Part 2**

Ask students to propose hypotheses regarding variables untested in this investigation, for example, the effect on the number of paper clips attracted if a high-voltage dry cell were used. Do not have them actually test their hypotheses experimentally, as a higher-voltage dry cell could present safety hazards. Instead, encourage them to do library research to determine the answer.

# Chapter Review

## Content Review

### Multiple Choice

*Choose the letter of the answer that best completes each statement.*

1. The strength of the magnetic field of an electromagnet can be increased by
   a. increasing the number of coils in the wire only.
   b. increasing the amount of current in the wire only.
   c. increasing the amount of iron in the center only.
   d. all of these.
2. A generator can be considered the opposite of a(an)
   a. galvanometer. c. electric motor.
   b. transformer. d. electromagnet.
3. A device that changes the voltage of alternating current is a(an)
   a. transformer. c. generator.
   b. electric motor. d. galvanometer.
4. The scientist who discovered that an electric current creates a magnetic field is
   a. Faraday. c. Henry.
   b. Oersted. d. Maxwell.
5. A device with an electromagnet that continually rotates because of a changing electric current is a(an)
   a. doorbell. c. galvanometer.
   b. solenoid. d. electric motor.
6. The creation of an electric current by a changing magnetic field is known as
   a. electromagnetic induction.
   b. generation.
   c. transformation.
   d. stepping-up.

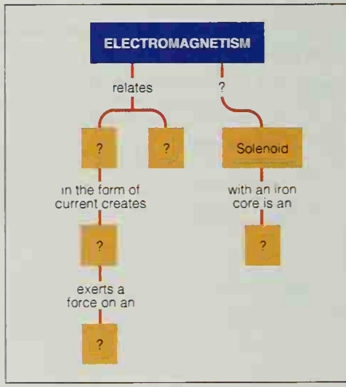
### True or False

*If the statement is true, write "true." If it is false, change the underlined word or words to make the statement true.*

1. The relationship between electricity and magnetism is called electromagnetism.
2. A solenoid with a piece of iron in the center is called an electromagnet.
3. A commutator and brushes are found in an electric motor running on direct current.
4. A generator is used to detect small currents.
5. In a generator, mechanical energy is converted to electric energy.
6. Large generators at power plants often get their mechanical energy from steam.
7. An induced current is produced by a changing electric field.
8. A transformer changes the voltage of an electric current.

### Concept Mapping

*Complete the following concept map for Section 3–1. Refer to pages P6–P7 to construct a concept map for the entire chapter.*






# Chapter Review

## ALTERNATIVE ASSESSMENT

The *Prentice Hall Science* program includes a variety of testing components and methodologies. Aside from the Chapter Review questions, you may opt to use the Chapter Test or the Computer Test Bank Test in your *Text Book* for assessment of important facts and concepts. In addition, Performance-Based Tests are included in your *Test Book*. These Performance-Based Tests are designed to test science process skills, rather than factual content recall. Since they are not content dependent, Performance-Based Tests can be distributed after students complete a chapter or after they complete the entire textbook.

## CONTENT REVIEW

### Multiple Choice

1. d
2. c
3. a
4. b
5. d
6. a

### True or False

1. T
2. T
3. T
4. F, galvanometer
5. T
6. T
7. F, magnetic
8. T

### Concept Mapping

Row 1: makes possible a
Row 2: Electricity, Magnetism
Row 3: Magnetism; Electromagnet
Row 4: Electric Current

## CONCEPT MASTERY

1. Yes. When a wire carrying electric current is placed in a magnetic field, the wire moves. When the direction of the current is reversed, the wire moves in the opposite direction.

2. An electric motor is a device that changes electric energy into mechanical energy. The current in an AC electric motor switches direction 120 times per second, changing the poles of the magnet, allowing the armature to rotate continuously. The commutator in a DC electric motor switches the direction of the current. Changing the poles of the magnet, allowing the armature to rotate continuously.

3. A galvanometer that detects small currents consists of a coil of wire suspended in a magnetic field and connected to an electric circuit. When a current flows through the wire, the magnetic field exerts a force on the wire, causing the needle of the galvanometer to deflect. As the current changes direction, the direction of the needle deflection also changes.

4. A typical generator consists of a rotatable coil attached to a power source and placed within a magnetic field. As the coil rotates, it cuts magnetic lines of force in various directions, producing AC, or alternating current.

5. Oersted discovered that a magnetic field is produced around a wire that is conducting an electric current. Faraday discovered that electricity can be induced from a magnetic field. The two discoveries are essentially "opposite sides of the same coin": They both show that magnetism and electricity are related in such a way that one can be produced in the presence of the other.

## Concept Mastery

*Discuss each of the following in a brief paragraph.*

1. Does a magnetic field exert a force on a wire carrying electric current? Explain.
2. Describe how an electric motor operates. How does its operation differ depending on the type of current used to run the motor?
3. Explain how a galvanometer works.
4. Describe how a generator operates.
5. Describe the discoveries of Oersted and Faraday. How are these discoveries related?
6. What is a solenoid? An electromagnet?
7. What is a step-up transformer? A step-down transformer? Why are transformers important for the transmission of electricity?

## Critical Thinking and Problem Solving

*Use the skills you have developed in this chapter to answer each of the following.*

1. **Making comparisons** Explain the difference between an electric motor and an electric generator in terms of energy conversion.
2. **Making diagrams** Use a diagram to show how the rotation of a wire loop in a generator first induces a current in one direction and then a current in the other direction.
3. **Applying concepts** The process of electromagnetic induction might seem to disobey the law of conservation of energy, which says that energy cannot be created. Explain why this is actually not so.
4. **Applying definitions** Indicate whether each of the following characteristics describes (a) a step-up transformer, (b) a step-down transformer, (c) both a step-up and a step-down transformer.
   a. Voltage in the secondary coil is greater.
   b. Involves electromagnetic induction.
   c. Voltage in the primary coil is greater.
   d. Used in doorbells and model trains.
   e. Consists of two insulated coils wrapped around opposite sides of an iron core.
   f. More loops in the secondary coil.
5. **Making inferences** Explain why a transformer will not operate on direct current.

6. **Making comparisons** Thomas Edison originally designed a power plant that produced direct current. Alternating current, however, has become standard for common use. Compare and contrast the two types of currents in terms of production and use.
7. **Using the writing process** Several devices that work on the principle of electromagnetism and electromagnetic induction have been mentioned in this chapter. Choose three of these devices and imagine what your life would be like without them. Write a short story or a poem that describes your imaginings.

**6.** A solenoid is a coil of wire that acts as a magnet when current is applied. An electromagnet is a solenoid with a magnetic material such as iron inside it.

**7.** A step-up transformer is a device consisting of two coils and an iron core that combine to increase the voltage of alternating current. A step-down transformer is a device consisting of two coils and an iron core that combine to decrease the voltage of alternating current. The resistance of lengthy transmission wires causes heat to be generated and energy to be lost—step-up and step-down transformers decrease the amount of energy lost through transmission.

### CRITICAL THINKING AND PROBLEM SOLVING

**1.** An electric motor converts electric energy into mechanical energy. An electric generator converts mechanical energy into electric energy.

**2.** Diagrams will vary, depending on the student. Diagrams should clearly indicate the various stages in the rotation—perpendicular to the lines of force, then parallel, then perpendicular, and so on.

**3.** Electromagnetic induction does not involve creation of energy, but rather the conversion of energy. Energy from the changing magnetic field becomes energy in the electric field that results.

**4.** Step-up transformer: a, f; step-down transformer: c, d; both: b, e.

**5.** The current induced in the second coil results from a changing magnetic field. A changing magnetic field is created only by a changing, or alternating, electric current.

**6.** Early electricity production was direct current and used the assistance of commutators to change it into alternating current. The development of the transformer gradually changed production of electricity to alternating current, which was more convenient to generate and transmit than direct current was. Examples of alternating and direct current use will vary, depending on the student.

**7.** Short stories or poems will vary but should reflect dependence on electricity in our daily lives.

### KEEPING A PORTFOLIO

You might want to assign some of the Concept Mastery and Critical Thinking and Problem Solving questions as homework and have students include their responses to unassigned questions in their portfolio. Students should be encouraged to include both the question and the answer in their portfolio.

### ISSUES IN SCIENCE

The following issue can be used as a springboard for discussion or given as a writing assignment:

Some of the electricity consumed in the United States is generated in nuclear power plants. In these plants, water is heated to steam, and the steam is used to turn turbine blades, which in turn rotate coils within generators, producing electricity. After the steam is used, it is released into the atmosphere, and the warm water is piped to cooling ponds for reuse after it has cooled. Are these steam and hot-water waste products of a nuclear power plant contributing to global warming? Why or why not?

# Chapter 4 Electronics and Computers

## CHAPTER OVERVIEW

The development of electronic devices has led from their inception to their applications in computers. Electronics is the study of the release, behavior, and effects of electrons as it relates to use in helpful devices. Electronics began with the invention of the diode vacuum tube, which serves as a one-way gate for electrons. Diode vacuum tubes are used as rectifiers, and triode vacuum tubes are used as amplifiers.

Modern electronics began with the use of semiconductors to make solid-state diodes and transistors. Produced by doping, or loading, crystals like silicon with impurities, solid-state devices can replace many large vacuum tubes with a single, tiny integrated circuit.

Radio and television are created by producing, transmitting, and amplifying audio and visual signals.

Computers have become relatively pervasive in our society today. The main components of a computer are the CPU, main memory, input device, disk drive, and output device. A computer needs programs, or operating instructions, to function. The binary number system is used by computers.

## 4–1 ELECTRONIC DEVICES

### THEMATIC FOCUS

The purpose of this section is to introduce students to various electronic devices. Electronics is the study of the release, behavior, and effects of electrons as it relates to use in helpful devices.

Students will learn that electronics began with the invention of the vacuum tube and its applications as diodes, amplifiers, and rectifiers.

Modern electronics began with the invention of solid-state devices, or sandwiches of semiconductors that behave in the same manner as vacuum tubes, but with more power, precision, and efficiency. Transistors and integrated circuits have miniaturized the world of electronics.

The themes that can be focused on in this section are systems and interactions, unity and diversity, and evolution.

***Systems and interactions:** The release, behavior, and control of electrons constitute the foundation of electronics. The development of new technologies and devices can be traced back to an understanding of electrons and how they function.

**Unity and diversity:** Diodes and transistors play different roles in an electronic device. Diodes serve as one-way paths for currents and have specific applications in electronic theory. Transistors amplify currents and also have specific applications. Even though they are both different, both have been essential to the development of modern electronics.

**Evolution:** Electronics has undergone a rapid evolution from an era of vacuum tubes and large machinery to the development of integrated circuits and microcomputers.

### PERFORMANCE OBJECTIVES 4–1

**1. Define electronics.**
**2. Describe the function of an amplifier.**
**3. Compare two different types of semiconductors.**
**4. Compare transistors to a triode vacuum tube.**

### SCIENCE TERMS 4–1

**electronics p. P88**
**vacuum tube p. P89**
**rectifier p. P90**
**diode p. P90**
**amplifier p. P90**
**triode p. P90**
**solid-state device p. P91**
**semiconductor p. P91**
**doping p. P92**
**transistor p. P93**
**integrated circuit p. P93**
**chip p. P93**

## 4–2 TRANSMITTING SOUND

### THEMATIC FOCUS

In this section students are introduced to telephone and radio communication. The telephone consists of a transmitter and a receiver, and the operation of both is explained.

The production, transmission, and reception of radio signals are also explained. Particular emphasis is given to the energy conversions that are required to convert sound waves into electrical signals, electromagnetic waves, back into electrical signals, and finally back into sound.

The themes that can be focused on in this section are energy and stability.

***Energy:** Electromagnetic waves can be used to carry information in the form of energy from one place to another.

***Stability:** Radio waves used in radio communication all travel at the same speeds.

### PERFORMANCE OBJECTIVES 4–2

**1. Describe the operation of a telephone transmitter.**
**2. Identify the energy conversions required to complete a telephone call.**
**3. Trace the energy conversions required to hear a radio broadcast.**

### SCIENCE TERMS 4–2

**electromagnetic wave p. P95**

## 4–3 TRANSMITTING PICTURES

### THEMATIC FOCUS

This section explains to students how pictures are transmitted by the use of a cathode-ray tube, or CRT. The operation of a CRT is examined, and students discover that electrons are emitted by a hot filament and directed at a screen that is coated with one or more fluorescent materials. The position and intensity of the electron beam are changed so that as the fluorescent material in different areas of a screen are hit by electrons, the areas emit different amounts of light, and a picture is formed.

A color television picture tube has three electron beams aimed at screen materials that emit light of different colors. Various color pictures are formed as the three materials emit different amounts of the primary colors.

The theme that can be focused on in this section is patterns of change.

**Patterns of change:** Picture and sound broadcasts are converted into electric signals and then placed on electromagnetic waves (radio waves) that are sent out through the air. Receivers convert the signals back into their original forms.

### PERFORMANCE OBJECTIVES 4-3

**1. Describe the operation of a cathode-ray tube.**
**2. Explain why a color television picture tube requires three electron guns.**

### SCIENCE TERMS 4-3

**cathode-ray tube p. P99**

## 4-4 COMPUTERS

### THEMATIC FOCUS

The purpose of this section is to explain to students the development of the computer. Students learn that a computer is an electronic device that performs calculations and processes and stores information. Modern computers have tremendous potential—they guide spaceships, forecast weather, and diagnose disease. But computers were not always like the computers of today.

Students learn that the first computer was developed in the late 1800s and used punch cards to help count the census statistics of 1890.

The first large-scale computer was developed in 1946 by the United States Army. Costing millions of dollars and consisting of millions of vacuum tubes, it occupied an entire warehouse and was constantly breaking down. As the demand for computers increased, so did the technology.

The computers of today consist of hardware and software. The hardware of a computer includes such things as the central processing unit (CPU), or "brain" of the computer; main memory, or a place for information storage; an input device such as a typewriter keyboard or optical scanner; a disk drive to read information such as programmed instructions; and output devices such as monitors and printers.

The role of software to computing is also explained, and students learn that software is the program or set of instructions that the computer follows. A computer follows instructions by counting two numbers at a time. The system that uses only two numbers is the binary system of numbers, more commonly known as base two. Computer circuits contain many electronic switches, and these switches can either be on or off. A computer stores information or follows instructions based on the arrangement of on/off switches.

The theme that can be focused on in this section is scale and structure.

***Scale and structure:** The future of computers is, in a sense, very large and very small. Microprocessors can hold entire processing capabilities on one very small chip. And groups of computers, sometimes thousands of miles apart, are being linked together electronically to form supercomputers.

### PERFORMANCE OBJECTIVES 4-4

**1. Trace the role of electronics in computers.**
**2. List the parts of a computer and their function.**
**3. Describe the binary system and its relationship to computers.**

### SCIENCE TERMS 4-4

**hardware p. P104**
**central processing unit p. P104**
**main memory p. P104**
**input device p. P104**
**disk drive p. P104**
**output device p. P105**
**modem p. P106**
**software p. P106**
**binary system p. P106**
**bit p. P106**
**byte p. P106**

## Discovery Learning

### TEACHER DEMONSTRATIONS MODELING

#### A Glimpse of the Past

Display two radios: one, a modern transistor radio, the other a table-top model containing vacuum tubes. Making sure each radio is unplugged, carefully remove the cabinet of each and allow students to visually inspect the contents. If the parts of a vacuum tube are visible, point these out to students.

After assembling each radio, turn on both devices for the same amount of time and at the same volume. After several minutes, have students note the energy wasted in the forms of heat and light by the older radio.

#### Your Blinker Is On

To show that household electricity or current is AC, or alternating current, obtain a digital clock that has red light-emitting diodes forming the numerals. With the clock plugged in, move it rapidly in front of the students. A darkened room works best and should allow the numbers to appear as dashed lines, showing that they are actually flashing on and off at 60 Hz.

CHAPTER 4

# *Electronics and Computers*

## INTEGRATING SCIENCE

This physical science chapter provides you with numerous opportunities to integrate other areas of science, as well as other disciplines, into your curriculum. Blue numbered annotations on the student page and integration notes on the teacher wraparound pages alert you to areas of possible integration.

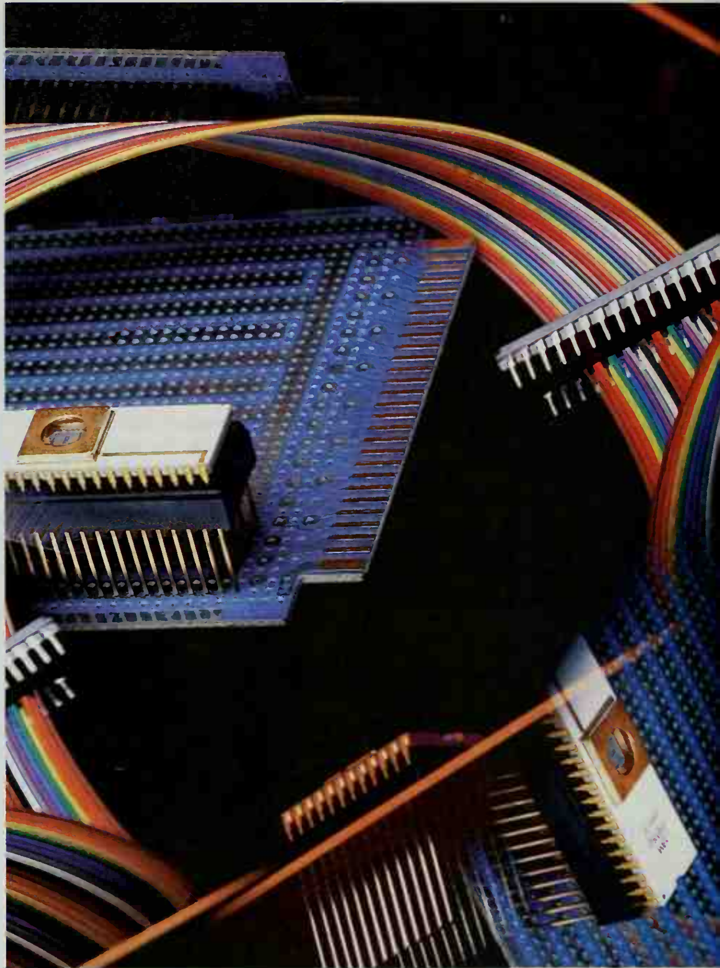
In this chapter you can integrate physical science and electrons (p. 88), physical science and kinetic energy (p. 89), life science and EKG (p. 91), language arts (pp. 95, 106, 107), physical science and electromagnetic waves (p. 95), social studies (pp. 97, 103), physical science and fluorescence (p. 99), physical science and color (p. 100), mathematics (pp. 103, 106), earth science and ozone depletion (p. 103), and life science and the nervous system (p. 105).

## SCIENCE, TECHNOLOGY, AND SOCIETY/COOPERATIVE LEARNING

Computers, perhaps more than any other devices, illustrate the relationship among science, technology, and society. By applying the scientific principles of electronics, computer technology was developed. This technology, in turn, has had an impact on every facet of our lives—entertainment, communication, business, travel, medicine, banking, law enforcement, and so forth.

Using computers to age missing children can provide new leads for law enforcement officials and encouragement to parents. Computer age-progression specialists can produce an accurate image of what a child would look like as he or she gets older. This process of aging children improves the chances of a child being spotted, identified, and returned to his or her parents.

Computer robots that can replace workers in a variety of industries are



## INTRODUCING CHAPTER 4

### DISCOVERY LEARNING

▶ *Activity Book*

Begin teaching the chapter by using the Chapter 4 Discovery Activity from the *Activity Book*. Using this activity, students will simulate the actions of a computer and sort data by asking questions that require only a yes or no answer.

### USING THE TEXTBOOK

Have students observe and read the caption to the picture on page P86.

• **What do you observe in the picture?** (Electronic components.)

• **What are some of the names of the different electronic components shown in this picture?** (Accept logical answers. If some students are able to recognize printed circuit boards and semiconductors or "chips," ask them to volunteer

# Electronics and Computers

## Guide for Reading

*After you read the following sections, you will be able to*

**4–1 Electronic Devices**

- Define electronics.
- Describe the structure and applications of vacuum tubes.
- Relate semiconductors to the operation of transistors and integrated circuits.

**4–2 Transmitting Sound**

- Explain how a radio and a telephone work.

**4–3 Transmitting Pictures**

- Describe the operation of a cathode-ray tube and its use in a television set.

**4–4 Computers**

- Discuss the development and the components of a modern computer.

It was 1952—and not many people were familiar with computers. In fact, there were some who had never heard the word. But on Election Day of that year, millions of Americans came face to face with the computer age.

The presidential contest that year pitted Republican Dwight D. Eisenhower against Democrat Adlai E. Stevenson. Early in the evening, even before the voting polls had closed, newscaster Walter Cronkite announced to viewers than an "electronic brain" was going to predict the outcome of the election. The "electronic brain" was the huge UNIVAC I computer.

What UNIVAC predicted, based on just 3 million votes, was a landslide victory for Eisenhower. An amazed nation sat by their television sets into the early hours of the morning, convinced that the "electronic brain" could not have predicted as it did.

UNIVAC was not wrong, however. When all the votes were counted, the computer's prediction turned out to be remarkably close to the actual results. In this chapter you will learn about some of the devices that have brought the computer age and the electronic industry to where it is now.

### Journal *Activity*

***You and Your World*** Do you watch television often? If so, what kinds of shows do you watch? If not, why not? Television is an electronic device in widespread use in modern society. In your journal, compare the positive contributions television has made with its negative aspects. Explain how you would improve the use of television.

*A photographer's view of some of the electronic components that make computer technology possible.*



other things they know, as a motivational activity for others.)

• **In what ways do you use electronic components such as these, or others, in your life?** (Answers will vary. Students might suggest home computers, stereo systems, calculators, and so on.)

Point out that electronic components have greatly influenced the lives of students, whether they realize it or not.

Have students read the chapter introduction on page P87.

• **When elections are held today, and the predictions of winners and losers are made with respect to those elections, do people react the same way as they did in 1952?** (No.)

• **Why not?** (Accept reasonable explanations. Lead students to infer that computer technologies have become a routine part of our lives.)

Ask student to list the computer-controlled devices that they might encounter during the course of an average day.

viewed as a way of reducing manufacturing costs so that our goods can compete in an increasingly competitive world marketplace. Computer-operated "money machines" enable us to conduct our banking business without ever going to a bank or interacting with a person.

Increasingly, computers are allowing us to perform functions that required human assistance in the past. What will the future hold for our society? What impact will application of computer technology in industry have on our economy? What are the political implications of an increasingly automated society? What will happen to our environment in this "age of computers"?

**Cooperative learning:** Using preassigned lab groups or randomly selected teams, have groups complete one of the following assignments:

• Using the information in this chapter and reference books, make an illustrated time line that traces the development of the computer.

• Provide groups with the following scenario: The automobile industry has decided to completely automate the manufacturing and production of cars and trucks by using computerized robots on the assembly line. Predict the economic, political, social, and environmental consequences if such a decision were made today.

Use Cooperative Learning in the *Teacher's Desk Reference.*

## JOURNAL ACTIVITY

You may want to use the Journal Activity as the basis for a class discussion. Discuss how television technology has changed over the years, using your own experiences to stimulate the discussion or using the experiences of a volunteer parent or grandparent. Also discuss with students the kinds of changes that they would make in their lifestyles if television were not available to watch and whether it is fair to limit the amount of television someone could watch. Students should be instructed to keep their Journal Activity in their portfolio.

# 4-1 Electronic Devices

## MULTICULTURAL OPPORTUNITY 4-1

Have your students conduct a survey of electrical appliances in their homes. After a discussion of the variety of appliances available, have them think about how their lives would be different if they didn't have electricity. What kinds of things that they now take for granted would they not be able to do?

## ESL STRATEGY 4-1

Have students circle the word that is not part of a vacuum tube: emitter, collector, filament, protector. Ask students to provide definitions for the remaining terms and explain how a vacuum tube controls the flow of electrons it creates when current passes through it.

Pair ESL students with English-speaking partners to prepare to answer these questions orally:

1. What are the two main groups of electron devices?
2. What advantage does one group have over the other?
3. What does a semiconductor do?
4. Which are the most commonly used semiconductors?

"Silicon Valley" is a name used to describe a specific region in California. Assign a group project to research this name. Have students report their findings to the class.

**Guide for Reading**

*Focus on these questions as you read*

- *What is electronics?*
- *How are electrons related to electronic devices?*

# 4-1 Electronic Devices

Were you awakened this morning by the buzz of an alarm clock? Did you rely on a radio or a cassette player to get the day started with music? Did your breakfast include food that was warmed in a microwave oven? Can you get through the day without using the telephone or watching television?

You probably cannot answer these questions without realizing that electric devices have a profound effect on your life. The branch of technology that has developed electric devices is called **electronics.** Electronics is a branch of physics closely related to the science of electricity. **Electronics is the study of the release, behavior, and control of electrons as it relates to use in helpful devices.** 1

Although electronic technology is relatively new—it can be traced back only 100 years or so—electronics has rapidly changed people's lives. For example, telephones, radio, television, and compact disc players have revolutionized communication and

**Figure 4-1** *Familiar electronic devices such as these have shaped the way people live and work. Have you used any of these devices?* 1

## TEACHING STRATEGY 4-1

### FOCUS/MOTIVATION

We cannot escape the influence of electronics in the modern world. Challenge students to name a career that has not been influenced by improvements in electronic technology. (They should have difficulty naming such a career.) Point out that understanding electronics is now essential for professions as diverse as agriculture, medicine, and auto mechanics.

Have a volunteer go to the chalkboard and list 25 careers that are suggested by other students. When the list is complete, discuss how electronic technology has influenced each of the careers.

### CONTENT DEVELOPMENT

For those students unsure of how AC (or alternating current) manages to do anything, discuss and review how the energy and information AC carries get transferred from place to place. In this transfer the electrons themselves do not have to move very far to pass energy and information to other electrons. This situation has a loose analogy to the motion of the particles of a medium disturbed by a longitudinal wave. (Have students recall the motion of particles in these waves.) Also point out that we do not purchase batteries to get electrons and that we do not buy electrons from the entertainment. Computers and robots have increased speed in business and industry. Electronic devices help physicians diagnose diseases and save lives. All forms of travel depend on electronic devices.

Perhaps you wonder how electronics differs from the study of electricity. After all, both deal with electrons and electric currents. The study of electricity concentrates on the use of electric currents to power a wide range of devices, such as lamps, heaters, welding arcs, and other electrical appliances. In such devices, the kinetic energy of moving electrons is converted into heat and light energy. Electronics treats electric currents as a means of carrying information. Currents that carry information are called electric signals. Carefully controlled, electrons can be made to carry messages, magnify weak signals, draw pictures, and even do arithmetic. 2

## Vacuum Tubes

The ability to carefully control electrons began with the invention of the **vacuum tube.** The American inventor Thomas Edison (also known as the inventor of the phonograph) invented the first vacuum tube but unfortunately did not realize its importance. A simple vacuum tube consists of a filament, or wire, and at least two metal parts called electrodes. When a current flows through the filament, much as it does through a light bulb, the filament gives off heat. This heat warms the electrodes. One of the electrodes gives off electrons when heated. For this reason, it is called an emitter. This electrode is negatively charged. The other electrode, which does not give off electrons, is positively charged. This electrode is called the collector because electrons flow to it from the negatively charged emitter. As a result, a current of electrons flows through the vacuum tube. Thus a vacuum tube is a one-way valve, or gate, for a flow of electrons. Electrons are permitted to move in only one direction through the vacuum tube.

Both the electrodes and the filament are contained in a sealed glass tube from which almost all the air has been removed. How does this fact explain the name given to this tube? A vacuum tube may have several other parts between the electrodes. It

### FIND OUT BY DOING

*Electronics in Your Home*

Over the course of a day, observe and make a list of all the electronic appliances you use in your home.

- Which of these appliances contain transistors? Cathode-ray tubes? Vacuum tubes? Integrated circuits?
- Do some appliances contain multiple types of devices? If so, which ones?



### ANNOTATION KEY

Answers

1 Answers will vary, depending on the student. (Applying concepts)

2 A sealed tube without air is basically a vacuum, thus the name. (Relating concepts)

Integration

1 Physical Science: Electrons. See *Matter: Building Block of the Universe,* Chapter 4.

2 Physical Science: Kinetic Energy. See *Motion, Forces, and Energy,* Chapter 5.

### FIND OUT BY WRITING

ELECTRONICS IN YOUR HOME

In this activity students reinforce the terms they have studied in this section by discovering electronic devices in their homes that employ various tubes and circuits. Most lists will contain television sets, radios, stereos, calculators, computers, and the like. Students may not be aware of many other devices in their homes that also use basic electronic concepts in their design or construction.

local power company when we use electricity.

#### Integration

Use the introduction and definition of the term *electronics* to integrate concepts of electrons into your lesson.

Use the example of how electronics differs from the study of electricity to integrate concepts of kinetic energy into your lesson.

### REINFORCEMENT/RETEACHING

Although this chapter may stand alone in terms of other chapters, it employs many terms and concepts that are mentioned in other areas of science, including chemistry, electricity, waves, and light. View each piece of technology as an application of science that students may already know by calling attention to any words and concepts developed previously.

### CONTENT DEVELOPMENT

Point out that the invention of the vacuum tube was, in essence, the catalyst that sparked electronic technologies. Though it may seem to students that electronic devices have already been a part of their lives, and thus of the lives of everyone else, remind them that the creation of electronic technologies (and electricity) is a relatively recent innovation. You might wish to ask students if they have ever seen a picture of a farm windmill or have actually seen one in person. If they have, point out that windmills are a testament to the fact that electricity was not always available and is only a recent invention and creation of science.

## BACKGROUND INFORMATION

### INVISIBLE FORCES

There are two primary types of invisible forces in electronics: electric fields and magnetic fields. Electric potential energy is stored as voltage in an electric field and as current in a magnetic field. Regardless of how the energy is stored, the potential energy is released into a circuit in the form of electric current.

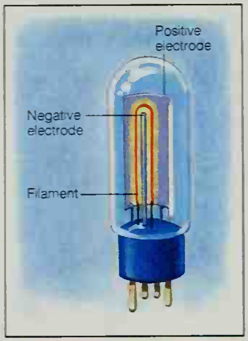



**Figure 4-2** *A diode is the simplest type of vacuum tube. In a diode, electrons flow in one direction, from the negative electrode to the positive electrode. Diodes are used as rectifiers in many electronic devices. Why?* 1

may also have charged plates or magnets that can bend the stream of electrons.

Because vacuum tubes produce a one-way current, they have many applications in electronics. Two important applications of vacuum tubes are as rectifiers and as amplifiers. Vacuum tubes also acted as switches in early electronic computers.

## Rectifiers

A **rectifier** is a vacuum tube that converts alternating current to direct current. The current supplied to your home is alternating current. Certain household appliances, however, cannot operate on alternating current. They need direct current. So these appliances have rectifiers built into their circuits. As the alternating current passes through the rectifier, it is changed into direct current.

The type of vacuum tube used most often as a rectifier is called a **diode.** A diode contains two electrodes. When alternating current is sent to a diode, the emitter will be charged by the current. However, it will emit a current only when it has a negative charge. And this happens only when the current is flowing in one direction. Thus the current leaving the diode is direct current.

Rectifiers are used in devices such as televisions, stereos, and computers. Converters that allow you to plug battery-operated devices into household electric outlets also contain rectifiers.

## Amplifiers

An **amplifier** is an electronic device that increases the strength of an electric signal. (Remember, an electric signal is a current that carries information.) In an amplifier, a small input current is converted to a large output current. The large output current produces a stronger signal. The strengthening of a weak signal is called amplification. Amplification is perhaps the most important function of an electric device.

Another type of vacuum tube, a **triode,** is often used for amplification. A triode consists of a filament, a plate, and a wire screen, or grid. The



## 4-1 (continued)

### CONTENT DEVELOPMENT

Distribute several vacuum tubes for inspection. Allow students to use a magnifying glass to view the electrodes of various tubes. If the tubes are no longer functional, you might choose to carefully break the surrounding glass of a tube and then allow students to closely inspect its contents. If the glass of a tube is broken for inspection, make sure the tube does not contain remnants of sharp glass and caution students to handle and distribute the tubes carefully, as the components of a vacuum tube are fragile and can be easily damaged. (Vacuum tubes may be available at a local television repair shop at no or minimal cost.)

### GUIDED PRACTICE

**Skills Development**

***Skill: Applying concepts***

On the chalkboard, diagram a circuit that includes a vacuum tube. Have students indicate the electron flow in the circuit and identify as many parts of the circuit as they can.

### ENRICHMENT

Point out that vacuum tubes glow when they are working properly.

• **What causes the glow in a vacuum tube?** (Accept logical responses. Point out that the area enclosed by a vacuum tube is not a pure vacuum. The glow results from some gas atoms deexciting after they have been hit by electrons. The dominant color, orange, is caused by the hot filament emitting the electrons.)

### CONTENT DEVELOPMENT

Students who are familiar with the law concerning the conservation of energy might be confused with the idea expressed in this section that a small signal produces a larger signal. For these students, make the distinction that the small signal fed to an amplifier does not proaddition of the grid allows the flow of electrons between the negatively charged emitter and the positively charged collector to be better controlled. The invention of the triode was responsible for the rapid growth of the radio and television industry.

Amplifiers strengthen both sound and picture signals. The signals that carry sound and picture information are often very weak as a result of traveling long distances through the air. By the time an antenna picks up the signals, they are too weak to produce an accurate copy of the original sound. Radio and television amplifiers strengthen the incoming signals. Fully amplified signals can be millions or billions of times stronger than the signal picked up by the antenna.

Without amplifiers, devices such as hearing aids, public-address systems, tape recorders, and radar would not operate. Amplifiers are also essential to the operation of medical instruments used to diagnose certain injuries and diseases. Human heart waves and brain waves can be studied by doctors because the weak electric signals given off by these organs are amplified.

## Solid-State Devices

Electron devices can be divided into two main groups according to their physical structure. The vacuum tubes you have just read about make up one group. The other group consists of **solid-state devices.** Solid-state physics involves the study of the structure of solid materials.

From the 1920s until the 1950s, vacuum tubes dominated the world of electronics. In the 1950s, however, solid-state devices took over. The reason for this is obvious: Solid-state devices have several advantages over vacuum tubes. They are much smaller and lighter than vacuum tubes and give off much less heat. They also use far less electric power, are more dependable, and last longer. And in most cases, they are less expensive.

In solid-state devices, an electric signal flows through certain solid materials instead of through a vacuum. The use of solid-state devices was made possible by the discovery of **semiconductors.** Semiconductors are solid materials that are able

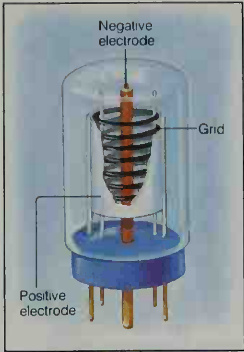



**Figure 4–3** *A triode vacuum tube consists of a filament, a plate, and a grid. The addition of a grid allows the electron flow to be amplified, or strengthened. Triodes are used in microphones to amplify sound.*

P ■ 91

ANNOTATION KEY

**Answers**

1 Rectifiers convert alternating current, or AC, to direct current, or DC—a two-way flow to a one-way flow. (Applying definitions)

**Integration**

1 Life Science: EKG. See *Human Biology and Health,* Chapter 6.

duce a large output signal. Rather, it controls a large current, prompting the large current to take the shape of the small input signal. If students are having difficulty understanding this concept, an analogy might be drawn to a sporting event: At a sporting event, the crowd is capable of creating large noises. The cheerleaders cannot make as much noise as the crowd, but they can signal the crowd to make certain noises. The cheerleaders create and control the loud sounds of the crowd with their own weaker signals.

### GUIDED PRACTICE

**Skills Development**

***Skill: Inferring***

Most students may be familiar with a stethoscope, which is worn by many doctors. If they are not, describe a stethoscope to them or obtain one, if possible, and allow students to use it.

**• A stethoscope is used to listen to the noises made by a heart. A stethoscope usually does not contain any electronic components of any kind. Is the stethoscope an amplifier? Why or why not?** (Encourage debate and accept all logical responses.)

### CONTENT DEVELOPMENT

Point out that an amplifier is an electronic device that increases the strength of electric (sound or picture) signals. The text mentions that without amplifiers and amplification, devices such as hearing aids, public-address systems, tape recorders, radar systems, and medical instruments would not operate. Challenge students to create lists containing the names of other devices that could not operate without the use of amplifiers. You might issue this challenge in the form of a class brainstorming activity, allowing students several minutes to think of as many devices as possible.

**• • • • Integration • • • •**

Use the discussion of the use of amplification by the health-care industry to integrate EKG concepts into your lesson.

## FACT AND FIGURES

### SEMICONDUCTOR CRYSTALS

A semiconductor, by its very nature, conducts electricity. But certain properties of a semiconductor depend on its temperature. At a temperature of absolute zero, most pure semiconductors would become insulators.

**Figure 4-4** *Devices that used vacuum tubes were large, heavy, and cumbersome. They also gave off a considerable amount of heat. Devices that use semiconductors can be made extremely small. In addition, they are more dependable, last longer, use less energy, and give off less heat.*

**Figure 4-5** *Doping a semiconductor material increases its conductivity. In an n-type, the impurity adds extra electrons that can flow. In a p-type, doping creates holes that are missing electrons. What impurity is used to make an n-type semiconductor? A p-type?* 2

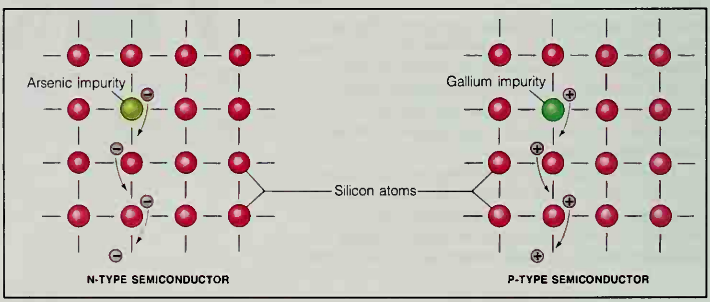
to conduct electric currents better than insulators do but not as well as true conductors do.

Silicon and germanium are the most commonly used semiconductors. These elements have structures that are determined by the fact that their atoms have four outermost electrons. Silicon and germanium acquire their usefulness in electronics when an impurity (atoms of another element) is added to their structure. Adding impurities to semiconductors increases their conductivity. The process of adding impurities is called **doping.**

There are two types of semiconductors. These types are based on the impurity used to dope the semiconductor. If the impurity is a material whose atoms have 5 outermost electrons (such as arsenic), the extra electrons will not fit into the structure of the semiconductor. Thus the doping contributes extra electrons that are somewhat free to move and that can form a current. This type of semiconductor is called an n-type, meaning negative-type. Silicon doped with arsenic is an n-type semiconductor.

If a semiconductor is doped with a material whose atoms have three outermost electrons (such as gallium), there will be empty holes in the semiconductor's crystal structure. These holes can also be used to form a current. Semiconductors doped with atoms that have fewer electrons, which is equivalent to saying extra protons, are called p-type semiconductors. Silicon doped with gallium is a p-type semiconductor. What do you think p-type means? 1

The arrangement of impurities on one type of semiconductor allows current to flow in only one




## 4-1 (continued)

### CONTENT DEVELOPMENT

Explain that a crystal diode of a very small size can be constructed from a tiny piece of silicon and a thin platinum wire. The silicon acts as a cathode, and the platinum acts as a collecting plate. Because the electrons travel directly from the silicon to the platinum, the cathode does not have to be heated, nor does the device require a vacuum. Semiconductor diodes are even smaller—replacing the platinum wire with another tiny crystal. These principles require that a crystal's affinity for electrons be enhanced or diminished by doping it with impurities; in other words, loading it with extra protons or electrons.

### ENRICHMENT

Because of students' familiarity with many devices that use transistors, they should be more familiar with transistors than with their bulky predecessors, vacuum tubes. You might wish to pose a question, however, about how the performance of large vacuum tubes could possibly be made to fit inside today's tiny electronic components.

### CONTENT DEVELOPMENT

Emphasize how the transistor is a miniature triode vacuum tube. Explain that a transistor is a sandwich of three semiconductor crystals. The center material, called the base, acts like the control grid of the triode vacuum tube. The weak input signal is directed to pass through the first material in a transistor—the emitter—to the base, or center material. A reverse current supplied to the base is directed toward the third material, the direction. Thus this type of semiconductor acts as a diode. A different arrangement of impurities produces another solid-state device, which you are now going to read about.

## Transistors

A **transistor** is a sandwich of three layers of semiconductors. A transistor is often used to amplify an electric current or signal. It is the arrangement of the impurities in the semiconductor that enables it to act as an amplifier. A weak signal, corresponding to a weak current, enters the transistor and is amplified so that a strong signal is produced.

Transistors come in a variety of shapes and sizes. Perhaps you are familiar with some of them. Transistors are commonly used in radios, televisions, stereos, computers, and calculators. The small size, light weight, and durability of transistors have helped in the development of communication satellites. 1

**Figure 4–6** *Transistors come in a variety of shapes and sizes. What does a transistor do?* 3

## Integrated Circuits

When you studied electric circuits in Chapter 1, you learned that a circuit can consist of many parts connected by wires. Complicated circuits organized in this fashion, however, become very large. In the 1960s, scientists found a way to place an entire circuit on a tiny board, thereby eliminating the need for separate components. This new type of circuit is known as an **integrated circuit.** An integrated circuit combines many diodes and transistors on a thin slice of silicon crystal. This razor-thin piece of silicon is often called a **chip.** A single integrated circuit, or chip, may often contain thousands of diodes and transistors in a variety of complex combinations.

To turn a silicon chip into an integrated circuit, it must be doped in some places with arsenic and in other places with gallium. Certain areas of the chip become diodes, while other areas become transistors. Connections between these diodes and transistors are then made by painting thin "wires" on the chip. Wires are attached to the integrated circuit so it can be connected to other devices.



### ANNOTATION KEY

Answers

1 Positive-type. (Inferring)

2 Arsenic; gallium. (Applying facts)

3 Amplifies an electric signal. (Applying definitions)

Integration

1 Earth Science: Satellites. See *Exploring the Universe*, Chapter 3.

collector. The base acts as a barrier between the two currents. The current to the collector is controlled by the current to the emitter because there is voltage created between the edges of the base. Point out that the transistor amplifies a weak signal by allowing the weak signal to control a large current. For example, the large current in a portable radio is supplied by the battery. The weak signal comes from the radio station.

### • • • • Integration • • • •

Use the role of transistors in the development of communication devices to integrate concepts of satellites into your lesson.

### ENRICHMENT

Students have studied the connection between transistors and amplification devices. They may not realize, however, just how weak the signal amplified by an amplifier can be. Have interested students research the electronic technologies associated with space exploration such as the Voyager program. Specifically, have them discover the strength of the signal reaching Earth, billions of miles away, from the Voyager spacecraft.

### GUIDED PRACTICE

**Skills Development**

***Skill: Making observations***

The components discussed in this section of the text are very small. Students may not realize just how small these components are unless they could be compared against other objects of known sizes. Display several transistors and other electronic components, such as computer boards, to the class. Allow students sufficient time to handle and examine the objects, giving them the opportunity to realize the actual size of the different components explained in this section.

## ANNOTATION KEY

Integration

1 Language Arts

2 Physical Science: Electromagnetic Waves. See *Sound and Light*, Chapter 3.

## FIND OUT BY WRITING

### TELEPHONE AND RADIO HISTORY

This activity will help students better understand some historical developments of the radio and telephone. Check students' work for scientific and historical accuracy.

**Integration:** Use the Find Out by Writing feature to integrate language arts skills into your science lesson.

## 4–1 (continued)

### CONTENT DEVELOPMENT

Point out that because the effects of a semiconductor involve only a few atoms, the size of a diode or a transistor needs to be only a few atoms thick. Integrated circuits combine many diodes and transistors on single crystals. A thin slice of silicon called a wafer is coated with an insulator that leaves the silicon exposed in certain locations. These exposed locations receive a coating of a second semiconductor of opposite type, thus forming a diode. Transistors are formed if a third layer is added before the component is sealed with another insulating layer.

Connections between these diodes and transistors may be made by painting thin "wires" on them or even by scratching the insulating layer to expose a channel of silicon. Wires are then attached so that external circuits may be connected to the integrated circuit chip.

### INDEPENDENT PRACTICE

**Section Review 4–1**

1. Electronics studies the release, behavior, and effects of electrons used to carry information. Electricity uses electric currents to power devices by converting the energy of moving electrons into heat and light energy.

2. Electrons in a vacuum tube form a current; a vacuum tube is used as a rectifier to change alternating current (AC) into direct current (DC); vacuum tubes are used in amplifiers to increase the strength of an electric signal.

3. Semiconductors are devices that can conduct electricity better than insulators can, but not as well as metals can.

4. An integrated circuit combines many diodes and transistors on a thin slice of silicon crystal, and a single integrated circuit may often contain thousands of diodes and transistors in a variety of complex combinations. An advantage of integrated circuits is that they are much smaller and have greater performance than vacuum tubes.

5. Definitions may vary, with students suggesting that *rectify* means "to change" and *amplify* means "to make

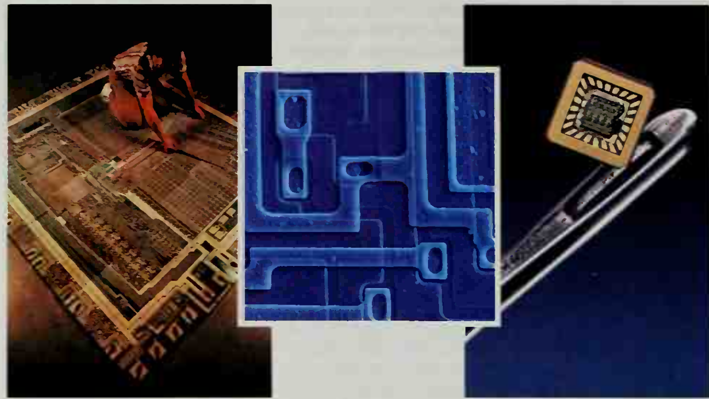


**Figure 4–7** *An integrated circuit, or chip, contains thousands of diodes and transistors on a thin slice of silicon crystal (right). A computer scientist designs a new computer chip by first drawing a large version and then having the design miniaturized (left). Magnified 175 times by a scanning electron microscope, the integrated circuit paths can be seen (center). A human hair is wider than 150 of these paths!*

Integrated circuits are used as amplifiers and switches in a wide variety of devices. Computers and microcomputers, calculators, radios, watches, washing machines, refrigerators, and even robots use integrated circuits.

### 4–1 Section Review

1. What is electronics? How is it different from the study of electricity?
2. How are electrons used in a vacuum tube? How is a vacuum tube used as a rectifier? As an amplifier?
3. What is a semiconductor?
4. How are semiconductors used to make integrated circuits? What are some advantages of the use of integrated circuits?

**Connection—*Language Arts***

5. The words rectify and amplify are not limited to scientific use. Explain what these words mean and give examples of their use in everyday language. Then explain why they are appropriate for the electronic devices they name.

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## 4–2 Transmitting Sound

**Guide for Reading**

*Focus on this question as you read.*

▶ *How do sound-transmitting devices work?*

Since the first telegraph line was connected and the first telegraph message was sent in 1844, people have become accustomed to instant communication. Each improvement in the speed, clarity, and reliability of a communication device has been based on a discovery in the field of electronics.

One particular discovery that is the basis for many devices used to transmit information is an interesting relationship between electricity and magnetism. The discoveries made by Oersted, Faraday, and others that you have read about in Chapter 3 clearly illustrate that electricity and magnetism are related. Another scientist, James Clerk Maxwell, used the discoveries of his predecessors to open a new world of scientific technology.

Maxwell showed that all electric and magnetic phenomena could be described by using only four equations involving electric and magnetic fields. Thus he unified in one theory all phenomena of electricity and magnetism. These four equations are as important to electromagnetism as Newton's three laws are to motion.

Perhaps the most important outcome of Maxwell's work is the understanding that not only does a changing magnetic field give rise to an electric field, but a changing electric field produces a magnetic field. In other words, if a magnetic field in space is changing, like the up and down movements of a wave, a changing electric field will form. But a changing electric field will also produce a changing magnetic field. The two will keep producing each other over and over. The result will be a wave consisting of an electric field and a magnetic field. Such a wave is called an **electromagnetic wave.** Electromagnetic waves are like waves on a rope except that they do not consist of matter. They consist of fields.

You are already more familiar with electromagnetic waves than you may realize. The most familiar electromagnetic wave is light. All the light that you see is composed of electromagnetic waves. The microwaves that heat food in a microwave oven are also electromagnetic waves. The X-rays that a doctor takes are electromagnetic waves. And as you will

### FIND OUT BY WRITING

*Telephone and Radio History*

The invention of the telephone and the invention of the radio were two important advances in electronic technology. Using books and other reference materials in the library, find out about the invention of each. Be sure to include answers to the following questions.

**1.** Who invented the device?

**2.** When was it invented?

**3.** Were there any interesting or unusual circumstances surrounding the invention?

**4.** How was the invention modified through the years?

Present the results of your research in a written or oral report. Accompany your report with illustrations.

1



## 4–2 Transmitting Sound

### MULTICULTURAL OPPORTUNITY 4–2

Have your students investigate the life and works of Granville T. Woods (1856–1910). Sometimes known as the "Black Edison," Woods was a prolific inventor, specializing in electromechanical devices. His patents include a device that was a cross between a telephone and a telegraph (which he termed a "telegraphony"), an invention that allowed telegraph messages to be sent to moving trains, as well as a dimmer system for theater lights.

### ESL STRATEGY 4–2

Make sure students understand the usage of the term *vice versa* before beginning the activity. Have students determine which source—radio, telephone, or electromagnetic wave—produces each phenomenon or product:

**1.** Sound vibrations change into electric signals, which are then changed back into sound.

**2.** Change in magnetic field causes a changing electric field to form, and vice versa.

**3.** Sound vibrations change into electromagnetic waves and are changed back into sound.

**greater." Examples of how these words are used in everyday language and reasons why these words are appropriate for use in electronics will vary, depending on the student.**

### REINFORCEMENT/RETEACHING

Monitor students' responses to the Section Review questions. If students appear to have difficulty with any of the questions, review the appropriate material in the section.

### CLOSURE

▶ *Review and Reinforcement Guide*

At this point have students complete Section 4–1 in the *Review and Reinforcement Guide.*

### TEACHING STRATEGY 4–2

### FOCUS/MOTIVATION

Have students list and discuss the various ways in which sound is transmitted in their lives. Examples may include television, radio, stereo systems, and the like. Then have students describe a typical day in their life in which none of these sound-transmitting devices were available. Students will realize how these important and convenient devices are often taken for granted and what society might be like without these electronic devices.

### CONTENT DEVELOPMENT

Remind students of the energy conversions studied earlier. Have them recall that although energy is conserved in these conversions, amplifiers are required because of losses, mainly in the form of heat—hence the role of the transistor.

**● ● ● ● Integration ● ● ● ●**

Use the description of different types of light to integrate concepts of electromagnetic waves into your lesson.

## HISTORICAL NOTE

### GUGLIELMO MARCONI

The Italian electrical engineer Guglielmo Marconi is sometimes referred to as "The Father of Radio." Building on an established body of work by the German mathematician and physicist Heinrich Hertz, Marconi built a device to detect, or receive, radio waves. Gradually, Marconi built devices that were able to send and receive radio waves. In 1895, he sent a signal 1 mile; in 1896, 9 miles; in 1897, 12 miles; in 1898, 18 miles. On December 12, 1901, Marconi succeeded in sending a radio wave from England to Newfoundland, Canada. The date of this transmission of radio waves across the Atlantic Ocean is the reference date often given for the invention of radio.

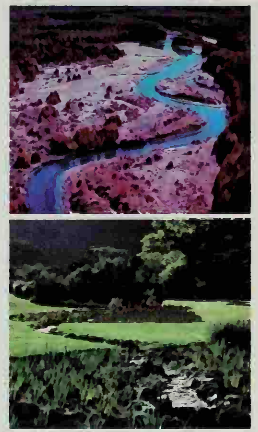


**Figure 4–8** *Electromagnetic waves in the form of X-rays enable you to see the forks, pen, and toothbrush in this person's intestine! Another type of EM wave allows scientists to study the composition of the brain and other parts of the body. Believe it or not, this photograph of a river was taken in total darkness using infrared waves. What type of electromagnetic wave can be seen in the bottom photograph?* 1

soon learn, the prediction and verification of electromagnetic waves opened up a whole new world of communication—from the first wireless telegraph to radio and television to artificial space satellites.

## Radio Communication

Would you be surprised to learn that radio broadcasting once played the same role that television plays today? People would gather around a radio to listen to a variety of programs: musical performances, comedy shows, mystery hours, and news broadcasts. Today, radio broadcasting is still a great source of entertainment and information. But its role has been greatly expanded.

Radios work by changing sound vibrations into electromagnetic waves called radio waves. The radio waves, which travel through the air at the speed of light, are converted back into sound vibrations when they reach a radio receiver.

A radio program usually begins at a radio station. Here, a microphone picks up the sounds that are being broadcast. An electric current running through the microphone is disturbed by the sound vibrations in such a way that it creates its own vibrations that match the sound.

The electric signals that represent the sounds of a broadcast are now sent to a transmitter. The transmitter amplifies the signals and combines them with a radio wave that will be used to carry the information. How the wave carries the information determines if the information will be broadcast as AM or FM radio. The final wave carrying the signal is then sent to a transmitting antenna. The antenna sends

96 ■ P

### 4–2 (continued)

#### GUIDED PRACTICE

**Skills Development**

***Skill: Sequencing events***

List the following words or phrases related to sound on the chalkboard. As students are completing the activity, play a radio softly, if possible.

- transmitter
- receiving antenna
- radio waves
- receiver amplifier
- microphone
- transmitting antenna
- sound waves
- receiver
- loudspeaker
- audio signal

Instruct students to sequence the pieces of information to describe the process of being able to hear the sounds transmitted by a radio station.

#### INDEPENDENT PRACTICE

▶ *Multimedia* ◀

You might want to use the Interactive Videodisc called Invention: Mastering Sound to reinforce the concepts of sound and its history. The videodisc explores the various criteria that describe many inventors, describes an introduction to the process of inventing, and establishes the contributions related to sound of three inventors. After viewing the videodisc, have students work in small groups to discuss and debate the future evolution of sound. Have the groups decide what they feel will be the next major sound-related invention.

#### CONTENT DEVELOPMENT

Students' familiarity with using the telephone may not always enhance their interest in studying or understanding this device. Point out that many people today install and sometimes even service their own telephones. Mention that if

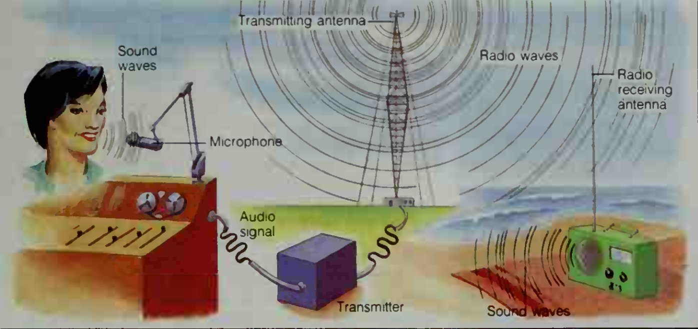



**Figure 4-9** *Radios work by converting sound vibrations into electromagnetic waves. The waves are amplified and sent out into the air. Picked up by a receiving antenna, the radio waves are converted back into sound waves. What else does the receiver do with the radio waves?* 3

the radio waves out into the air. Why do you think many radio stations locate their antennas at high elevations, in open areas, or on top of towers? 2

Radio waves are converted back into sound waves by means of a radio receiver. A radio receiver picks up and amplifies the radio waves originally sent out from a radio station. When a radio receiver picks up sounds corresponding to a specific frequency, it is described as being tuned in.

Have you ever wondered how a telephone call can be made from a moving vehicle such as a car or an airplane? Cellular telephones (movable telephones) use signals that are sent out by an antenna as radio waves. Other antennas pick up the radio waves and convert them back into sound. To understand more about cellular telephones, you must first learn how a telephone operates.

## Telephone Communication

Have you ever stopped to think about the amazing technology that enables you to talk to someone else, almost anywhere in the world, in seconds? The device that makes this communication possible is the telephone. The first telephone was invented in 1876 by Alexander Graham Bell. Although modern telephones hardly resemble Bell's, the principle on which all telephones work is the same. A telephone sends and receives sound by means of electric signals. A telephone has two main parts.



### ANNOTATION KEY

**Answers**

1 Visible light. (Applying concepts)

2 To minimize interference and absorption of wave energy from other buildings and to increase the distance that the wave is able to travel. (Inferring)

3 Amplifies them. (Inferring)

**Integration**

1 Social Studies

students know the parts of a telephone and how it works, they may be able to avoid a future repair bill or at least be able to speak intelligently to a repair person in the event something is wrong with the telephone.

### Integration

Use the example of worldwide communication by telephone to integrate concepts of social studies into your science lesson.

### ENRICHMENT

Amplifiers are required to prevent telephone signals from fading and losing strength over long distances. The energy of a transmission is gradually lost because a wire possesses resistance and current heats the wire. To improve transmission efficiency, telephone signals are often converted into light, which loses less energy, requires no wires, and travels somewhat faster than signals traveling through a wire. Fiber optics provides a method of sending a narrow beam of light through a plastic strand no thicker than a human hair. The fiber acts as a pipe or a path for light. A laser (or even a light-emitting diode) sends a pulsed beam of light corresponding in rhythm with the varying sound waves into one end of the fiber. The light bounces off the walls of the fiber again and again in glancing reflections as if the surface of the fiber were a mirror. A light-sensitive diode at the far end converts the light back into an electrical signal.

In other situations, telephone transmission may be extended to include a transformation of the signal into electromagnetic waves if a portable telephone is used or if the signal is sent long distances via satellite or microwave relay towers.

## ANNOTATION KEY

Answers

1 In the transmitter; to amplify the electric signal. (Applying concepts)

Integration

1 Physical Science: Fluorescence. See *Sound and Light*, Chapter 3.

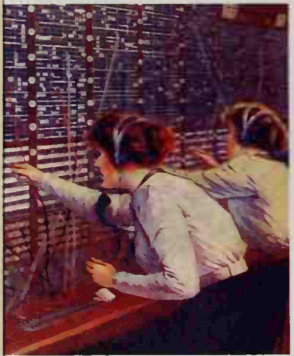


**Figure 4–10** *The first telephone was invented in 1876 by Alexander Graham Bell. Today, you push buttons or dial to make calls. But up until the early 1950s, telephone calls were placed by switchboard operators, whose familiar phrase was "Number, please."*

**TRANSMITTER** The transmitter is located behind the mouthpiece of a telephone. Sound waves produced when a person speaks into a telephone cause a thin metal disk located in the transmitter to vibrate. These vibrations vary according to the particular sounds. The vibrations, in turn, are converted to an electric current. The pattern of vibrations regulates the amount of electric current produced and sent out over telephone wires. You can think of the electric current as "copying" the pattern of the sound waves. The electric current travels over wires to a receiver.

**RECEIVER** The receiver, located in the earpiece, converts the changes in the amount of electric current sent out by a transmitter back into sound. The receiver uses an electromagnet to produce this conversion.

When the electric current transmitted by another telephone goes through the coil of the electromagnet, the electromagnet becomes magnetized. It pulls on another thin metal disk, causing it to vibrate. The vibrations produce sound waves that the listener hears.

Alexander Graham Bell used carbon grains in the transmitter to convert sound to electricity. Today's telephones use a small semiconductor crystal. Transistors then amplify the electric signal. In modern telephone earpieces, semiconductor devices have replaced electromagnets. And fiber-optic systems, in which the vibrations travel as a pattern of changes in a beam of laser light, are replacing copper cables used for ordinary transmission.

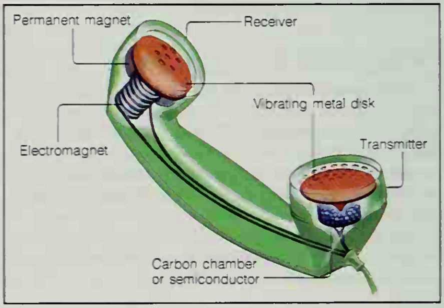



**Figure 4–11** *A telephone, consisting of a transmitter and a receiver, sends and receives sounds by means of electric signals. Where are transistors used? For what purpose?* 1



## 4–2 (continued)

### CONTENT DEVELOPMENT

If possible, have students disassemble an old or nonworking telephone. Ask them to identify the parts of the telephone, using Figure 4–11 as a reference.

### GUIDED PRACTICE

▶ *Laboratory Manual*

**Skills Development**

***Skill: Applying concepts***

At this point you may want to have students complete the Chapter 4 Laboratory Investigation in the *Laboratory Manual* called Constructing a Telephone. In this investigation students will build a simple device that illustrates the operation of a telephone transmitter.

### INDEPENDENT PRACTICE

**Section Review 4–2**

1. In devices that transmit sound, sound vibrations are changed into electromagnetic waves, which are then converted back into sound vibrations.
2. Transmitter and receiver. The transmitter detects vibrations, changing them into electric current; the receiver changes the electric current back into sound vibrations.
3. Answers may vary slightly. Students might suggest these steps: sound waves, microphone, audio signal, transmitter, transmitting antenna, radio waves, radio receiving antenna, receiver, amplifier, and sound.
4. Accept logical responses. Students might suggest that telephones and radios have become smaller in size and more portable.
5. Accept logical responses. Students might suggest that industry and business can now be conducted on a global, almost instantaneous scale.

### REINFORCEMENT/RETEACHING

Review students' responses to the Section Review questions. Reteach any material that is still unclear, based on students' responses.

## 4–2 Section Review

1. Describe the relationship between sound and electric current in devices that transmit sound.
2. Describe the two main parts of a telephone.
3. Describe the broadcast of a radio program.
4. How do you think solid-state devices have affected telephones and radios?

**Connection—*You and Your World***

5. How do you think radio communication has affected the development of business and industry?

# 4–3 Transmitting Pictures

**Guide for Reading**

*Focus on this question as you read.*

- *How does a cathode-ray tube operate?*

You would probably agree that a video game would be far less exciting if the images were unclear and did not move very quickly. The same is true of your favorite television show. The images on a video screen and a television screen are produced by a special type of vacuum tube.

## Cathode-ray Tubes

Television images are produced on the surface of a type of vacuum tube called a **cathode-ray tube,** or CRT. Cathode-ray tubes are also responsible for images produced by video games, computer displays, and radar devices.

**A cathode-ray tube is an electronic device that uses electrons to produce images on a screen.** This special type of vacuum tube gets its name from the fact that inside the glass tube, a beam of electrons (cathode rays) is directed to a screen to produce a picture. The electrons, moving as a beam, sweep across the screen and cause it to glow. The screen glows because it is coated with fluorescent material. Fluorescent material glows briefly when struck by electrons.

The electrons in a CRT come from the negatively charged filament within the sealed glass vacuum tube. An electric current heats the metal filament

**Figure 4–12** *When you play a video game, you are taking advantage of a cathode-ray tube.*


# *4-3 Transmitting Pictures*

### MULTICULTURAL OPPORTUNITY 4-3

Vladimir Kosma Zworykin was born in Russia but later became an American citizen. During his work at the Radio Company of America (RCA), he developed the first practical television camera, or iconoscope. He also was responsible for important refinements to the electron microscope.

### ESL STRATEGY 4-3

Have students explain the difference between the parts of a regular vacuum tube and a simple cathode-ray tube (or CRT), and the type of screen necessary for cathode rays to produce a picture. Then ask students to state another difference between a cathode-ray tube and the kind of screen used in a color television.

### CLOSURE

▶ *Review and Reinforcement Guide*

Students may now complete Section 4–2 in the *Review and Reinforcement Guide.*

### TEACHING STRATEGY 4-3

### FOCUS/MOTIVATION

Ask students to name various ways that they use or observe pictures transmitted through the air. (Students are likely to name television.) Also ask students to name various ways that pictures are transmitted through electric signals. (Students are likely to mention videotape and videocassette recorders, and the like.) Then ask students to name various ways that pictures are transmitted with the aid of light signals. (Students are likely to mention laserdiscs or videodiscs.)

Have students imagine what their lives would be like without such devices.

• **What do you think people did before television and radio?** (Accept reasonable responses. Students might suggest that people spent more time reading than they do today.)

You might want to discuss whether the fact that people read more years ago than they read now is an advantage or a disadvantage to the people of today.

### CONTENT DEVELOPMENT

Point out that a cathode-ray tube, or CRT, is an electronic device that uses electrons to produce images on a screen and that CRTs are responsible for the images produced by such things as video games, televisions, and computer displays or monitors.

**• • • • Integration • • • •**

Use the discussion of cathode-ray tubes to integrate the concept of fluorescence into your lesson.

# BACKGROUND INFORMATION

## SCREEN PHOSPHORS

The fluorescent materials, or phosphors, that are used to coat a video display are usually light metals in the form of sulfate, sulfide, and phosphate compounds. These compounds are manufactured into tiny, fine particles that are then used to coat the inside of a display. A monochrome (one-color) display usually receives one extremely thin, uniform coating. In a color display, the dots or vertical lines of a screen receive three coatings (red, blue, and green). The spaces around these color dots or lines are usually made to appear black to improve the contrast of the screen.

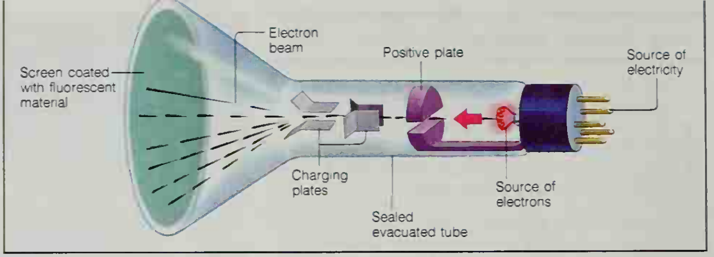



**Figure 4–13** *A cathode-ray tube is a sealed evacuated tube in which a beam of electrons is focused on a screen coated with fluorescent material. As electrons strike the fluorescent material, visible light is given off and an image is formed.*

and causes electrons to "boil" off it. The electrons are accelerated toward the screen and focused into a narrow beam. Because the electrons move so quickly in a concentrated beam, the source is sometimes referred to as an electron gun. The moving electrons produce a magnetic field that can be used to control the direction of the beam. Electromagnets placed outside the CRT cause the beam to change its direction, making it move rapidly up and down and back and forth across the screen.

At each point where the beam of electrons strikes the fluorescent material of the CRT screen, visible light is given off. The brightness of the light is determined by the number of electrons that strike the screen. The more electrons, the brighter the light. The continuous, rapid movement of the beam horizontally and vertically across the screen many times per second produces a pattern of light, or a picture on the screen. In the United States, the electron beam in a CRT traces 525 lines as it zigzags up and down, creating a whole picture 30 times each second. In some other countries the beam moves twice as fast, creating an even clearer image.

## Television Transmission

A cathode-ray tube in a color television set differs from a simple cathode-ray tube in two important ways. First, the screen of a color television set is coated with three different materials placed close together in clusters of dots or in thin stripes at each
1 point on the screen. Each material glows with a different color of light—red, blue, or green—when struck by a beam of electrons. Various colors are



## 4–3 (continued)

### CONTENT DEVELOPMENT

Point out that although the creation, transmission, and reception of a television signal are more complicated than those of a radio, for example, the production of the picture itself is much simpler.

Explain that the behavior of the electron beam is easy to explain according to the principle that opposite charges attract and like charges repel. Have students observe the electrostatic deflection system pictured in Figure 4–13. In it, the negative electrons are accelerated from the negative electrode toward the positive plate. Some electrons pass through a narrow opening in the plate and form a beam. The charging plates change the direction of the beam, with the size of the opposite charges on each pair of charging plates carefully controlled so that as the size of the charges change, the force on the negative electrons in the beam changes. The electron's vertical and horizontal paths change accordingly.

### • • • • Integration • • • •

Use the description of television transmission to integrate concepts of color into your lesson.

### GUIDED PRACTICE

**Skills Development**

***Skill: Applying concepts***

Students can transmit a picture to other students by establishing a grid system, then calling out a series of numbers. The first set of numbers called might represent the specific location on the grid, for example, and the second number might represent the brightness of a spot—from zero for black to three for bright white.

Students should agree on a particular format or style for the grid and then practice transmitting simple pictures to one another.

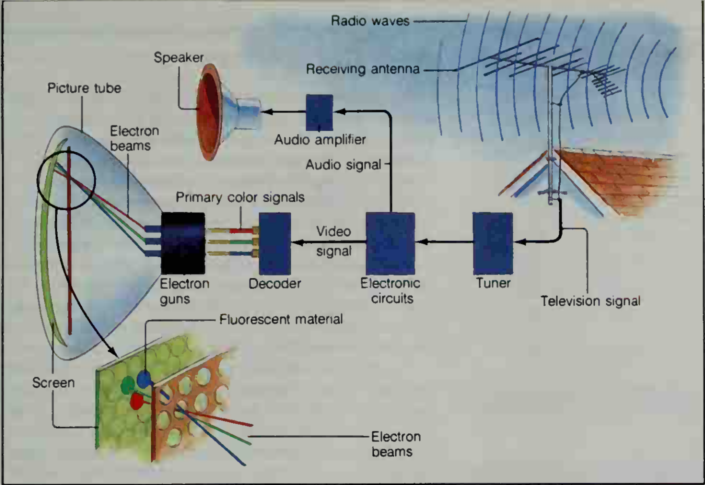



**Figure 4–14** *The CRT in a color television contains three electron guns—one each for red, blue, and green signals. The screen of the CRT is coated with three different fluorescent materials, each of which glows with a different primary color of light when struck by a beam of electrons.*

produced by adjusting the strengths of the electron beams. For example, red is produced when electrons strike only the red material. Purple is produced when electrons strike both red and blue material. When do you think white is produced? 1

Second, a color television CRT contains three electron guns—one for each color (red, green, and blue). The information for controlling and directing the beams from the three electron guns is coded within the color picture signal that is transmitted from a TV station.

## 4–3 Section Review

1. What is a cathode-ray tube? Describe how it works.
2. How does a color television CRT differ from a simple CRT?

**Critical Thinking—*Making Inferences***

3. Photographs of a TV picture taken with an ordinary camera often show only part of the screen filled. Explain why.



### ANNOTATION KEY

**Answers**

1 When electrons strike red, blue, and green fluorescent materials. (Inferring)

**Integration**

1 Physical Science: Color. See *Sound and Light*, Chapter 3.

### ECOLOGY NOTE

#### ELECTROMAGNETIC RADIATION

The proliferation of color televisions and computers increases our chances of being exposed to what is sometimes called electromagnetic radiation, or EMR. EMR is given off by screens such as those found on television sets and computers. Have interested students use research materials to discover the amount of radiation that is given off by these devices, the environmental impact of that radiation, and what is being done and can be done to limit the amount of radiation people might receive while watching television or working in front of a computer screen.

### INDEPENDENT PRACTICE

**Section Review 4-3**

1. It is an electronic device that uses electrons to produce images on a screen. An electric current heats a metal filament in the CRT, which then emits electrons. The electrons are accelerated through a magnetic field, which focuses the electrons into a beam. Electromagnets placed outside the CRT cause the beam of electrons to change direction. At each point where the electrons strike the fluorescent material of the CRT screen, visible light is given off.
2. In a color CRT, the screen is coated with three different materials that can glow with red, blue, or green light. A simple CRT has a coating of one material. A color CRT also differs from a simple CRT in that it has three electron "guns" rather than just one.
3. The electron beam in a CRT creates a whole picture 30 times per second. If the shutter speed on the camera is faster than this, the photograph will show only a partial picture because the entire picture will take 1/30 of a second to appear on the screen.

### REINFORCEMENT/RETEACHING

Monitor students' responses to the Section Review questions. If students appear to have difficulty with any of the questions, review the appropriate material in the section.

### CLOSURE

▶ *Review and Reinforcement Guide*

At this point have students complete Section 4–3 in the *Review and Reinforcement Guide.*

# 4-4 Computers

## MULTICULTURAL OPPORTUNITY 4-4

Have your students research the life and work of Admiral Grace Hopper. Admiral Hopper was a pioneer in the development of the computer and remained an ardent educator about computers until her death in 1992.

## ESL STRATEGY 4-4

Assign a group research project on futuristic computer techniques currently being developed to enhance the process known as Virtual Reality. Have other students investigate twenty-first-century career opportunities in the area of electronic arts and entertainment. Require brief individual reports and have students share their findings with the class.

**Guide for Reading**

*Focus on these questions as you read.*

- *What is a computer?*
- *How are the basic components of a computer related to its operation?*

## 4–4 Computers

Computers have quickly become a common sight over the past few decades. You see computers in stores, doctors' and dentists' offices, schools, and businesses. Perhaps you even have one in your home. **A computer is an electronic device that performs calculations and processes and stores information.** A modern electronic computer can do thousands of calculations per second. At equally incredible speed, it can file away billions of bits of information in its memory. Then it can rapidly search through all that information to pick out particular items. It can change numbers to letters to pictures to sounds—and back to numbers again.

Using these abilities, modern computers are guiding spaceships, navigating boats, diagnosing diseases and prescribing treatment, forecasting weather, and searching for ore. Computers make robots move, talk, and obey commands. Computers can play games and make music. They can even design new computers. The pages of this textbook were composed and printed with the help of a computer (although people still do the writing)!

### Computer Development

The starting point of modern computer development is thought to be 1890. In preparation for the United States census that year, Herman Hollerith

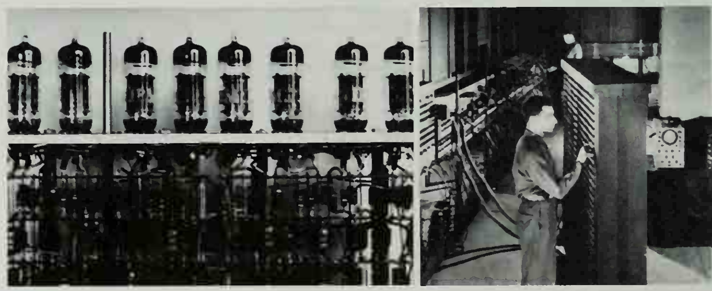


**Figure 4–15** *Early computers, which used large vacuum tubes were neither fast nor reliable. And like the ENIAC, they certainly were enormous in size! A modern computer that fits on a desk top once required an entire room.*



## TEACHING STRATEGY 4-4

### FOCUS/MOTIVATION

Computers seem to be everywhere. Although each integrated-circuit chip is a computer, it is difficult to observe because integrated-circuit chips can be very small and are often hidden in toys, watches, appliances, and many other items. Discuss with students the pervasive use of computers and computer technologies. Also discuss how an understanding of computer limitations can only enhance one's ability to use computers advantageously (even professionals are occasionally misled by computer program results if they do not fully understand what the computer can and cannot do for them).

### CONTENT DEVELOPMENT

Point out that computers did not always look and perform as they do today. Cite the example of the invention of Herman Hollerith. His electromagnetic machine allowed small electric currents to pass through holes that were punched into cards, activating counters. The cards were, in a sense, mechanical switches, turning currents on and off. By today's standards, the machine is primitive, at best. But in its day, the machine represented a radical technology in comparison to the way things were done previously.

- **If Hollerith's counting machine could be seen in a museum today, what do you think it might look like?** (Accept all reasonable descriptions. Lead students to infer that it would probably look primitive when compared to contemporary standards.)

Point out that Hollerith's machine is now more than 100 years old.

- **Think of the computers used today. One hundred years from now, how do you think people might describe our computers?** (Accept reasonable answers.

devised an electromagnetic machine that could handle information punched into cards. The holes allowed small electric currents to pass through and activate counters. Using this system, Hollerith completed the 1890 census in one fourth the time it had taken to do the 1880 census! Hollerith's punch card became the symbol of the computer age.

The first American-built computer was developed in 1946 by the United States Army. The Electronic Numerical Integrator and Calculator, or ENIAC, consisted of thousands of vacuum tubes and occupied a warehouse. It cost millions of dollars to build and maintain. It was constantly breaking down and had to be rebuilt each time a new type of calculation was done. ENIAC required great amounts of energy, generated huge amounts of heat, and was very expensive. By today's standards, ENIAC was slow. It could do only 100,000 calculations per second.

The first general-purpose computer was introduced in 1951. It was called the Universal Automatic Computer, or UNIVAC. UNIVAC was certainly an improvement over ENIAC, but it was still large, expensive, and slow.

Increased demand for computers encouraged more advanced computer technology. Technical breakthroughs such as transistors and integrated

## FIND OUT BY CALCULATING

*Computing Speed*

Shuffle a deck of playing cards. Have a friend time you as you sort the cards, first into the four suits, and then from the 2 through the ace in each suit. Determine how many sorts you made.

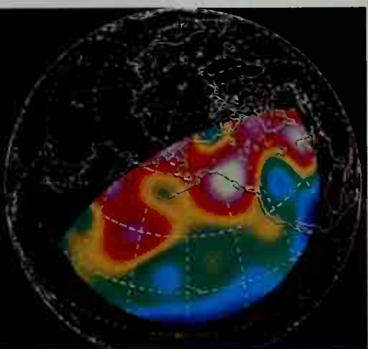
Calculate how many sorts you made per second.

A bank check-sorting machine can make 1800 sorts per minute.

- How much faster than you is this machine?

2

**Figure 4–16** *The uses of computers are wide and varied. Computer applications include the identification of worldwide ozone concentrations (bottom left), the analysis of the body mechanics of a runner (top), and the study of fractal geometry in mathematics (bottom right).*



### ANNOTATION KEY

Integration

1. Social Studies
2. Mathematics
3. Earth Science: Ozone Depletion. See *Exploring Planet Earth,* Chapter 1

### FIND OUT BY CALCULATING

COMPUTING SPEED

***Skills: Making comparisons, making computations***

***Materials: deck of playing cards, timing device***

The number of sorts that students will be able to perform per second will vary, depending on the student. The sorting speeds of students, however, will be substantially slower than the sorting speed of a bank check-sorting machine. Have students relate the speed of the machine to the many applications of computers that require fast computational calculations.

**Integration:** Use the Find Out by Calculating feature to integrate mathematics concepts into your science lesson.

Many students will probably suggest that our computers will look primitive when compared to machines of the future, just as Hollerith's 100-year-old machine appears primitive to us now.)

**• • • • Integration • • • •**

Use the discussion about the 1890 United States census to integrate social studies concepts into your science lesson.

Use Figure 4–16 to integrate concepts of ozone depletion into your lesson.

### GUIDED PRACTICE

**Skills Development**

***Skill: Making computations***

At this point have students complete the in-text Chapter 4 Laboratory Investigation called The First Calculator: The Abacus. In this investigation students will determine how an abacus works as a counting machine.

### ENRICHMENT

Ask students working in groups to identify ten objects in their homes that were manufactured to some degree with the use of computer technologies. Have groups identify the specific way or ways in which computer technologies are incorporated into each object. Then have groups discuss how the objects might be different if computer technologies were not used in their manufacture.

## INTEGRATION

### ASTRONOMY

Computers provided the Voyager spacecraft with the ability to perform research. Have students interested in astronomy use reference materials to discover more about the use of computers on exploratory spacecraft and have students share their findings with the class.

## CAREERS

### Computer Programmer

A **computer programmer** uses computer languages to tell computers what to do. Programmers must be able to think logically in order to understand the processes of the computer.

Computer programmers are trained in vocational schools or junior colleges. Many also have college degrees. For information write to the American Federation of Information Processing Societies, 1899 Preston White Drive, Reston, VA 22091.

circuits reduced the size and cost of computers. They also increased the efficiency, speed, and uses of computers. And equally important, they brought the computer within everyone's reach.

The future of computers lies in both the very small and the very large. Integrated circuits called microprocessors can hold an entire processing capability on one small chip. At the other extreme, groups of computers are being linked together to form supercomputers.

## Computer Hardware

Computer **hardware** refers to the physical parts of a computer. **Computer hardware includes a central processing unit, main storage, input devices, and output devices.**

The "brain" of a computer is known as the **central processing unit,** or CPU. A CPU controls the operation of all the components of a computer. It executes the arithmetic and logic instructions that it receives in the form of a computer program. A computer program is a series of instructions that tells the computer how to perform a certain task. A computer program can be written in one of several different computer languages.

The main storage of a computer is often referred to as the **main memory.** The main memory contains data and operating instructions that are processed by the CPU. In the earliest computers, the main memory consisted of thousands of vacuum tubes. Modern computer memory is contained on chips. The most advanced memory chip can store as much information as 1 million vacuum tubes can.

Data are fed to the central processing unit by an **input device.** One common input device is a keyboard. A keyboard looks very much like a typewriter. Using a keyboard, a person can communicate data and instructions to a computer. Other input devices include magnetic tape, optical scanners, and disk drives.

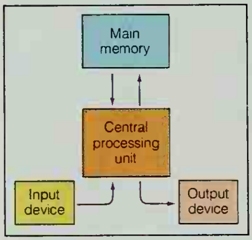



**Figure 4–17** *Computer hardware includes a central processing unit, main memory, an input device, and an output device. What is the function of each?* 1



## 4–4 (continued)

### REINFORCEMENT/RETEACHING

▶ *Activity Book*

Students who need practice on the concept of computer-information systems should complete the chapter activity Whose Data Bank Are You In? In this activity students will discover some of the various groups and organizations that may have information about them stored in computers.

### CONTENT DEVELOPMENT

Point out that every computer breakthrough has consisted of either a better way of storing information, such as replacing the holes in the punch cards of the counting system used in the 1890 census, or a faster way of turning a circuit on and off, such as replacing the mechanical switches. Stress that these improvements are based on electronic technology—first vacuum tubes, then semiconductors, and now integrated circuits. Students might be interested to learn that some integrated circuits can perform a billion calculations a second.

### GUIDED PRACTICE

▶ *Laboratory Manual*

**Skills Development**

***Skill: Relating facts***

At this point you may want to have students complete the Chapter 4 Laboratory Investigation in the *Laboratory Manual* called Creating a Computer Program. In this investigation students will discover how to use symbols that change a computer task into a flowchart.

### CONTENT DEVELOPMENT

If a computer is available, display the computer and all its components. Have students identify each component and classify the individual pieces in terms of main memory, input device, or output device. If possible, carefully remove the cabinet of a CPU and allow students to look inside it. Do not allow them, however, to touch or probe the contents.

### INDEPENDENT PRACTICE

▶ *Activity Book*

Students who need practice on the concept of diagramming steps should complete the chapter activity Flowcharting. In this activity students will create a flowchart for the various activities they

A **disk drive** reads information off a disk and nters it into the computer's memory or into the CPU. Information from a disk drive can be placed nto a computer very quickly.

Information produced by a computer can be emoved and stored on a disk. So a disk drive is also n **output device.** An output device receives data rom the central processing unit. Output devices nclude printers, cathode-ray tubes, magnetic tape lrives, and voice synthesizers. Even robots are output devices.

# CONNECTIONS

## 1 *The Human Computer*

The organization of the human body is pretty amazing, isn't it? Think of all the various organs constantly working independently as well as interacting with one another to keep you alive, healthy, and functioning normally. What's even more amazing is that the body does all its work without your having to think about it! You don't even have to worry about nourishing your body because it reminds you to do so by making you feel hungry. Now that's pretty awesome! What is even more incredible, perhaps, is that you have the ability to think, reason, reach conclusions, and use your imagination. What a wonderful device the human body is!

The organ of your body that controls the various body systems and is also the seat of intelligence is the *brain*. Different parts of the brain have different functions. One part enables you to coordinate your movements quickly and gracefully. Another part controls body processes, such as heartbeat, breathing, and blood pressure—not to mention swallowing, sneezing, coughing, and blinking. And still another part is responsible for your ability to think.

Many attempts have been made to simulate the activities of the brain. There is, in fact, a field of computer research that aims to create artificial intelligence—that is, computers capable of thinking and reasoning like humans. Currently, however, such attempts to unravel the interconnections of the human brain have proved largely unsuccessful. For now, at least, the human brain still holds its many secrets.



## ANNOTATION KEY

**Answers**

1 CPU: controls all computer operation; main memory: stores data and operating instructions; input device: feeds data to CPU; output device: receives data from CPU and displays the data. (Applying definitions)

**Integration**

1 Life Science: Nervous System. See *Human Biology and Health*, Chapter 6.

## CONNECTIONS

### THE HUMAN COMPUTER

This feature will enable students to relate the concept of a computer CPU to the "CPU" of their bodies—their brain. You may want to discuss the advantages and potential hazards of artificial intelligence with students or have them debate the advantages and potential hazards.

If you are teaching thematically, you may want to use the Connections feature to reinforce the themes of energy, scale and structure, systems and interactions, and stability.

**Integration:** Use the Connections feature to integrate concepts of the nervous system into your lesson.

perform during the course of a typical day.

### GUIDED PRACTICE

**Skills Development**

***Skill: Sequencing events***

Have students observe Figure 4–17. Then have them imagine a piece of information that they might want to have entered into the computer, acted upon by the computer, and demonstrated on the computer screen. Have students sequence the events that would occur, using the terms *main memory, CPU, input device,* and *output device.*

### ENRICHMENT

If any of your students have taken a computer programming class, have them volunteer to demonstrate how to write a detailed computer program that adds two numbers. Remind students that a CPU can perform only one task at a time, including checking to see that data are present; and retrieving data, reading data, storing data, and so on. When the program to add two numbers is finished, display it on the chalkboard and have students determine and count the number of individual steps required to add the two numbers.

## FIND OUT BY THINKING

HELPFUL PREFIXES

This activity serves to reinforce vocabulary skills and to give students a better knowledge of word derivations. Check students' sentences carefully to ensure that they have used each prefix correctly.

**Integration:** Use the Find Out by Thinking activity to integrate language arts skills into your science lesson.

## 4-4 (continued)

### CONTENT DEVELOPMENT

Describe the basic functions of computers, including problem solving and computer simulation, along with several of their specific applications. Also point out the prolific use of computers in data processing, word processing, and computer-aided design.

Explain that a computer that uses only two numbers to execute instructions performs its work using the binary system of numbers. If students appear to have some difficulty determining how a binary number system works, you might wish to ask a mathematics instructor to visit your class or provide you with helpful teaching strategies.

**Integration**

Use the introduction of the binary system to integrate mathematics concepts into your science lesson.

### INDEPENDENT PRACTICE

▶ *Activity Book*

Students who need help on the concept of how computers work should be provided with the chapter activity called A Checkers Computer. In this activity students will explore how a computer uses the binary number system to create bits and bytes.

### GUIDED PRACTICE

▶ *Laboratory Manual*

**Skills Development**

***Skill: Applying concepts***

At this point you may want to have students complete the Chapter 4 Laboratory Investigation in the *Laboratory Manual* called Constructing a Simple Computer Circuit. In this investigation students will explore how an off-on computer system works.

### INDEPENDENT PRACTICE

▶ *Activity Book*

Students who need help on the concept of binary number systems should be provided with the chapter activity called Counting to One Thousand Using Only Your Fingers. In this activity students will explore the system of numbering used by computers.

### ENRICHMENT

▶ *Activity Book*

Students will be challenged by the Chapter 4 activity in the *Activity Book* called Hexadecimal Numbers. In this activity students will explore a 16-digit system of numbers used by computers to perform calculations.

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Like a disk drive, a **modem** is an input and output device. A modem changes electronic signals from a computer into signals that can be carried over telephone lines. It also changes the sounds back into computer signals. A modem allows a computer to communicate with other computers, often thousands of kilometers away. As computers link in this way, they form a network in which information can be shared. A modem allows use of this network by accessing (getting) information from a central data bank. A data bank is a vast collection of information stored in a large computer.

### The Binary System

Computer hardware would be useless if computer **software** did not exist. **Software is the program or set of programs the computer follows.** Software must be precise because in most cases a computer cannot think on its own. A computer can only follow instructions. For example, to add two numbers, a program must tell a computer to get one number from memory, hold it, get the other number from memory, combine the two numbers, and print the answer. After completing the instruction, the computer must be told what to do next.

A computer can execute instructions by counting with just two numbers at a time. The numbers are 0 and 1. The system that uses just these two numbers is called the **binary system.**

Computer circuits are composed of diodes. As you learned in the previous sections, diodes are gates that are either open or closed to electric current. If the gate is open, current is off. If the gate is closed, current is on. To a computer, 0 is current off and 1 is current on. Each digit, then, acts as a tiny electronic switch, flipping on and off at unbelievable speed.

Each single electronic switch is called a **bit.** A string of bits—usually 8—is called a **byte.** Numbers, letters, and other symbols can be represented as a byte. For example, the letter A is 01000001. The letter K is 11010010. The number 9 is 00001001. 2

You do not need to be reminded of the importance of computers. You have only to look around you. The uses of computers are many, and their presence is almost universal. Any list of computer

#### FIND OUT BY THINKING

*Helpful Prefixes*

1 Several terms related to electronic devices may be easier for you to understand if you know the meaning of their prefixes. Find out the meaning of each prefix that is underlined in the words below. Then write a sentence explaining how the prefix will help you to learn the definition of the word.

- binary system
- diode
- integrated circuit
- microprocessor
- semiconductor
- triode
- transistor

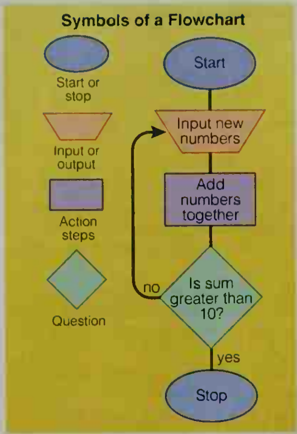
# PROBLEM Solving

## Go With the Flow

A computer follows a series of activities that take place in a definite order, or process. If you think about it, so do you. You get dressed one step at a time. When you follow a recipe, you add each ingredient in order.

It is useful to have a method to describe such processes, especially when writing computer programs. A flowchart is one method of describing a process. In a flowchart the activities are written within blocks whose shapes indicate what is involved in that step.

**Designing a Flowchart** It is a good thing you know how to write a flowchart because you are hosting the class luncheon today. But the chef that you have hired can cook only from a flowchart. Write a flowchart showing the chef how to prepare today's menu.




applications cannot really be completed today. For by the time today is over, another application will have been devised. The future of computers is exciting, indeed!

## 4–4 Section Review

1. What is a computer? How are its hardware and software involved in its operation?
2. What is a modem? How is it related to a data bank?
3. How is the binary system used by a computer?

**Critical Thinking—*Making Calculations***

4. Show how the following numbers would be represented by a byte: 175, 139, 3, 45, 17.

## FIND OUT BY READING

*Artificial Intelligence*

It is difficult to imagine using wires and crystals to construct a device that can think as you can. Read David Gerrold's *When H.A.R.L.I.E. Was One* and discover what such a device would be like. 3



ANNOTATION KEY

Integration
1 Language Arts
2 Mathematics
3 Language Arts

### PROBLEM SOLVING

GO WITH THE FLOW

This activity will help to reinforce the concept of how many events occur in a logical order, or sequence. Have students relate the logical steps involved in their flowcharts to the logical way in which a computer performs its tasks. The flowcharts designed by each student will vary, depending on the student.

### FIND OUT BY READING

ARTIFICIAL INTELLIGENCE

***Skill: Reading comprehension***

You may wish to have students prepare a brief written synopsis or an oral report of the assignment.

**Integration:** Use the Find Out by Reading activity to integrate language arts skills into your science lesson.

### INDEPENDENT PRACTICE

**Section Review 4–4**

1. An electronic device that performs calculations and processses information. The hardware of a computer executes instructions and commands, and the software provides the instructions, or the steps, for the computer to follow.
2. A modem is both an input and an output device. It can input or output information using phone lines and can connect with huge banks of information (data banks) for use by the computer operator.
3. The binary system is a mathematical system using only two numbers, 0 and 1. Because the switches in a computer can be in one of two positions, either on or off, the binary numbers refer to a switching position.
4. 10101111; 10001011; 00000011; 00101101; 00010001.

### REINFORCEMENT/RETEACHING

Review students' responses to the Section Review questions. Reteach any material that is still unclear, based on students' responses.

### CLOSURE

▶ *Review and Reinforcement Guide*

Students may now complete Section 4–4 in the *Review and Reinforcement Guide*.

# Laboratory Investigation

## THE FIRST CALCULATOR: THE ABACUS

### BEFORE THE LAB

1. Gather all materials at least one day prior to the investigation.
2. If an abacus cannot be obtained, one can easily be constructed by stringing beads or other objects on a string in a cardboard box. Do not let the lack of commercial apparatus deter you from this investigation.

### PRE-LAB DISCUSSION

Have students read the complete laboratory procedure.

- **What is the purpose of this investigation?** (To find out how an abacus can be used to count.)
- **What is an abacus?** (It is a system of beads used for counting.)
- **Does each column or row of beads represent a specific place value?** (Yes.)
- **Name the place values represented by your abacus.** (The greatest place value may vary, depending on the abacus—the ones through the millions place are usually represented.)

# Laboratory Investigation

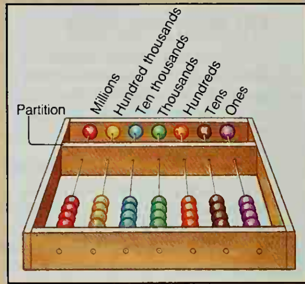
## The First Calculator: The Abacus

### Problem

How can an abacus serve as a counting machine?

### Materials *(per group)*

abacus




### Procedure

1. The columns of beads on the abacus represent, from right to left, units of ones, tens, hundreds, thousands, and millions.
2. The single bead in the upper section of each column, above the partition, equals 5 beads in the lower section of that column.
3. Always start from the lower section of the far right, or ones, column.
4. Count to 3 by sliding 3 beads of the ones column to the partition.
5. Continue counting to 8. Slide the fourth bead up to the partition. You should be out of beads in this section. Slide all 4 beads back down and slide the single bead from the upper section of this column down to the partition. Remember that the top bead equals 5 lower beads. Continue counting from 6 to 8 by sliding the beads in the lower section of the ones column up to the partition. Before doing any further counting, check with your teacher to see that you are using the abacus correctly.
6. Continue counting to 12. Slide the last bead in the ones column up to the partition. You should now have a total of 9. And you should be out of beads in the ones column. Slide all these beads back to their original zero position. Slide 1 bead in the lower section of the tens column up to the partition. This represents 10. Continue counting in the ones column until you reach 12.

### Observations

1. Count to each of these numbers on the abacus: 16, 287, 5016, 1,816,215.
2. How would you find 8 + 7 on the abacus? Start by counting to 8 on the abacus. Then continue adding 7 more beads Find the following sums: 7 + 8, 3 + 4, 125 + 58.

### Analysis and Conclusions

1. On what number system is the operation of the abacus based?
2. How does this compare with the operation of a computer?
3. **On Your Own** Try designing a number system that uses more than 2 numerals but fewer than 10. Count to 20 in your system.



### TEACHING STRATEGY

1. Remind students to follow the established laboratory procedure.
2. During the investigation, circulate through the room, offering assistance to students who are having difficulty learning to use an abacus.
3. Point out that although students may not perform computations quickly at first, their speed will increase as they practice using the abacus.

### DISCOVERY STRATEGIES

Discuss how the investigation relates to the chapter by asking open questions similar to the following:

- **How is an abacus like a computer?** (Accept reasonable answers. Students might suggest that both an abacus and a computer perform computations—comparing.)
- **How is an abacus different from a computer?** (Accept reasonable answers. Students might suggest that an abacus does not require an electrical energy source and a computer does, or that a computer can perform computations much faster than an abacus can—contrasting.)
- **The abacus was once a relatively common tool used for performing computations. Why do you think an abacus is not used much anymore?** (Lead students to infer that newer technologies, such as calculators and computers, tend to offer convenience and efficiency, which are not offered in older technologies—inferring, analyzing.)

# Study Guide

## Summarizing Key Concepts

### 4–1 Electronic Devices

▲ Electronics is the study of the release, behavior, and control of electrons as it relates to use in practical devices.

▲ In a tube in which most of the gases have been removed—a vacuum tube—electrons flow in one direction.

▲ A rectifier is an electronic device that converts alternating current to direct current.

▲ An amplifier is an electronic device that increases the strength of an electric signal.

▲ Semiconductors are materials that are able to conduct electric currents better than insulators do but not as well as true conductors do.

▲ Adding impurities to semiconductors is called doping.

▲ An integrated circuit combines diodes and transistors on a thin slice of silicon crystal.

### 4–2 Transmitting Sound

▲ Radios work by changing sound vibrations into electromagnetic waves, or radio waves.

▲ A telephone sends and receives sound by means of electric signals. A telephone has two main parts: a transmitter and a receiver.

### 4–3 Transmitting Pictures

▲ A cathode-ray tube, or CRT, is an electronic device that uses electrons to produce images on a screen.

▲ A cathode-ray tube in a color television set contains three electron guns—one each for red, blue, and green signals.

### 4–4 Computers

▲ Integrated circuits called microprocessors can hold the entire processing capability on one small chip.

▲ Computer hardware consists of a central processing unit, main storage, input devices, and output devices.

▲ A computer program is a series of instructions that tell the computer how to perform a certain task.

## Reviewing Key Terms

*Define each term in a complete sentence.*

### 4–1 Electronic Devices

electronics
vacuum tube
rectifier
diode
amplifier
triode
solid-state device
semiconductor
doping
transistor
integrated circuit
chip

### 4–2 Transmitting Sound

electromagnetic wave

### 4–3 Transmitting Pictures

cathode-ray tube

### 4–4 Computers

hardware
central processing unit
main memory
input device
disk drive
output device
modem
software
binary system
bit
byte



### OBSERVATIONS

**1.** The settings should be as follows: (16) ones column: upper bead down, one lower bead up; tens colum: upper bead up, one lower bead up; (287) ones column: upper bead down, two lower beads up; tens: upper bead down, three lower beads up; hundreds: upper bead up, two lower beads up; (5016) ones: upper bead up, one lower bead up; tens: upper bead up, one lower bead up; hundreds: upper bead up, no lower beads up; thousands: upper bead down, no lower beads up; (1,816,215) ones: upper bead down, no lower beads up; tens: upper bead up, one lower bead up; hundreds: upper bead up, two lower beads up; thousands: upper bead down, one lower bead up; ten thousands: upper bead up, one lower bead up; hundred thousands: upper bead down; three lower beads up; millions: upper bead up, one lower bead up.
**2.** Students must add the proper number of beads to show the correct answers: 15, 7, and 183, respectively.

### ANALYSIS AND CONCLUSIONS

**1.** Base 10, or decimal number system.
**2.** A computer works in base 2, or the binary number system.
**3.** Individual designs will vary, depending on the student. Designs may be tested using computations with known answers.

### GOING FURTHER: ENRICHMENT

#### Part 1

Have students perform simple subtraction exercises on the abacus. You may wish to demonstrate several sample exercises, if necessary.

#### Part 2

Have students design an abacus that works on the binary system. Have them repeat the investigation using this abacus.

# Chapter Review

## ALTERNATIVE ASSESSMENT

The *Prentice Hall Science* program includes a variety of testing components and methodologies. Aside from the Chapter Review questions, you may opt to use the Chapter Test or the Computer Test Bank Test in your *Test Book* for assessment of important facts and concepts. In addition, Performance-Based Tests are included in your *Test Book*. These Performance-Based Tests are designed to test science process skills, rather than factual content recall. Since they are not content dependent, Performance-Based Tests can be distributed after students complete a chapter or after they complete the entire textbook.

## CONTENT REVIEW

### Multiple Choice

1. b
2. a
3. c
4. b
5. c
6. b
7. d
8. c

### True or False

1. T
2. T
3. T
4. F, three
5. F, ENIAC
6. T
7. F, input
8. T
9. T

### Concept Mapping

Row 1: Electronics
Row 2: has produced the
Row 3: Solid-state devices; electrons
Row 4: that strengthens a signal is a; Semiconductors
Row 5: Rectifier; Integrated circuit

# Chapter Review

## Content Review

### Multiple Choice

*Choose the letter of the answer that best completes each statement.*

1. Diode vacuum tubes are used as
   a. transistors. c. amplifiers.
   b. rectifiers. d. triodes.
2. Which electronic device was particularly important to the rapid growth of the radio and television industry?
   a. triode c. punch card
   b. diode d. disk drive
3. Which of the following is a semiconductor material?
   a. copper c. silicon
   b. plastic d. oxygen
4. A sandwich of three semiconductor materials used to amplify an electric signal is a(an)
   a. diode. c. integrated circuit.
   b. transistor. d. modem.
5. Radios work by changing sound vibrations into
   a. cathode rays. c. electric signals.
   b. gamma rays. d. bytes.
6. Which is not an advantage of solid-state devices in telephones and radios?
   a. smaller size
   b. increased cost
   c. better amplification
   d. greater energy efficiency
7. The physical parts of a computer are collectively referred to as computer
   a. software. c. programs.
   b. peripherals. d. hardware.
8. Which is computer software?
   a. printer c. program
   b. disk drive d. memory

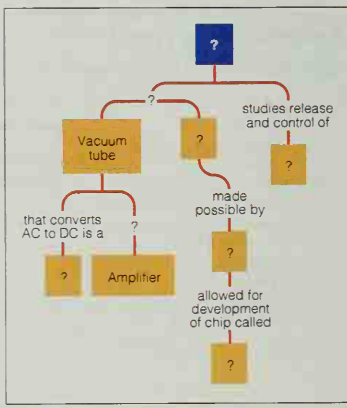
### True or False

*If the statement is true, write "true." If it is false, change the underlined word or words to make the statement true.*

1. A device that converts alternating current to direct current is a rectifier.
2. A telephone sends and receives sound by means of electric current.
3. The beam of electrons in a cathode-ray tube produces a picture.
4. A color television CRT has two electron guns.
5. The first American-built computer was UNIVAC.
6. Microprocessors are integrated circuits that can hold the entire processing capability of a computer on one chip.
7. Output devices feed data to a computer.
8. A data bank is a vast collection of information stored in a large computer.
9. A string of bits, usually eight in number, is called a byte.

### Concept Mapping

*Complete the following concept map for Section 4–1. Refer to pages P6–P7 to construct a concept map for the entire chapter.*




## CONCEPT MASTERY

1. Electron beams produce images on screens coated with fluorescent materials, and the predictable behavior of electrons allows science and technology to create devices that use electrons and improve the quality of our lives.
2. A rectifier is a diode vacuum tube that converts alternating current (AC) to direct current (DC). An amplifier uses a triode vacuum tube to increase the strength of an input signal.
3. A semiconductor is a material that is able to conduct electric currents better than insulators but not as well as metals. Semiconductors are doped to increase their conductivity.
4. Radio communication uses electromagnetic waves.
5. A telephone transmitter converts sound waves into electric waves, and a telephone receiver converts the electric waves from the transmitter back into sound waves.
6. Sounds waves enter a microphone, are converted into electromagnetic waves, and are sent by a transmitter to a trans-

## :oncept Mastery

*iscuss each of the following in a brief paragraph.*

1. Why are electrons important to electronic devices? Give some examples.
2. Compare the functions of rectifiers and amplifiers. What type of vacuum tube is used for each?
3. Describe a semiconductor. Why are semiconductors doped?
4. What connection between electricity and magnetism is used in radio communication systems?
5. How does a telephone work?
6. How is a radio show broadcast?
7. In what ways are semiconductor diodes better than their vacuum tube ancestors?
8. Describe how a cathode-ray tube creates a picture.
9. What is a computer? What are some uses of computers?
10. What system is used in computers and calculators? Explain how it works.

## :ritical Thinking and Problem Solving

*'se the skills you have developed in this chapter to answer each of the following.*

1. **Making diagrams** Draw a diagram that shows how the four main hardware components of a computer are related.
2. **Sequencing events** The sentences below describe some of the energy conversions required for a local telephone call. Arrange them in proper order.
   a. Sound vibrates a metal plate.
   b. An electromagnet is energized.
   c. A vibrating magnet produces sound.
   d. Vibrating vocal cords produce sound.
   e. Mechanical energy is converted into an electric signal.
3. **Classifying computer devices** Many methods for putting data into a computer are similar to methods for getting data out of a computer. Identify each of the following as an input device, an output device, or both: typewriter keyboard, CRT, printer, optical scanner, magnetic tape, disk drive, punched cards, voice synthesizer.
4. **Applying concepts** A program is a list of instructions that tells a computer how to perform a task. Write a program that describes the steps involved in your task of waking up and arriving at school for your first class.
5. **Making calculations** The pictures on a television screen last for one thirtieth of a second. How many pictures are flashed on a screen during 30 minutes?
6. **Using the writing process** The electronics industry and the development of computers have evolved quite rapidly. You yourself are even witnessing obvious changes in the size and capabilities of electronic devices such as calculators, video games, computers, VCRs, compact disc players, and videodiscs. Write a story or play about how you think electronic devices will affect your life thirty or forty years from now.

nitting antenna. The radio waves travel hrough the air, are received by a receiving antenna, and are amplified and con-'erted into sound waves.

'. Semiconductors are smaller, lighter, onger lasting, more dependable, and :ooler, and use far less power than vacıum tubes.

3. The cathode-ray tube, powered by :lectricity, emits a controlled beam of :lectrons that strike fluorescent materi-ıls, giving off visible light.

). A computer is an electronic device hat performs calculations and processes information. The uses of computers may vary, depending on the application.

**10.** The binary system controls the operation of computers. It is a system of two-position electronic switches—on or off.

### CRITICAL THINKING AND PROBLEM SOLVING

**1.** Check each diagram for accuracy.

**2.** The correct order is (d) vibrating vocal cords produce sound, (a) sound vibrates a metal plate, (e) mechanical energy is converted into an electric signal, (b) an electromagnet is energized, and (a) a vibrating magnet produces sound.

**3.** Both: magnetic tape, disk drive; input: typewriter keyboard, punched cards, optical scanner; output: CRT, voice synthesizer, printer.

**4.** Check students' programs more for the logic they employ than whether the program could actually be run by a computer. Students should not be expected to be computer programmers, but they should be able to apply what they have learned to what the program would need to tell the computer.

**5.** 54,000 pictures.

**6.** Stories or plays will vary, depending on the student.

### KEEPING A PORTFOLIO

You might want to assign some of the Concept Mastery and Critical Thinking and Problem Solving questions as homework and have students include their responses to unassigned questions in their portfolio. Students should be encouraged to include both the question and the answer in their portfolio.

### ISSUES IN SCIENCE

The following issues can be used as springboards for discussion or given as writing assignments:

**1.** Vacuum tubes are essentially obsolete, now that the production of semiconductor devices has been perfected. Many other modern inventions have also become obsolete within a century of their invention: The fountain pen and the telegraph are two such inventions. What other "modern" inventions are obsolete? Can you predict several items that will be replaced by improved versions?

**2.** Television has had a profound impact on society. Could the inventors have foreseen the positive and negative effects of television? Do the positive effects outweigh the negative? Should the development of television have been stopped until only positive effects could be assured?

## ADVENTURES IN SCIENCE

THE SEARCH FOR SUPERCONDUCTORS

### Background Information

Superconductivity was discovered in 1911 by H. Kamerlingh Onnes. Onnes was studying the electrical conductivity of mercury within a few degrees of absolute zero (0°K or −273°C). Onnes observed that the resistance of mercury dropped sharply to an almost immeasurably small amount at a temperature of 4.2°K. He named this point the transition temperature, which is the temperature at which resistance to conducting an electric current drops to nearly 0 ohms.

Soon after its discovery, superconductivity was found to be a property of such common metals as lead and tin, in addition to mercury. At first, scientists believed that the phenomenon of superconductivity was quite rare and was limited to only a few substances. After a while, however, experiments showed that this property occurs quite frequently. Some 26 metallic elements are known to be superconductors, and 10 others become superconductors under pressure or when prepared as thin films. In addition, thousands of compounds and alloys have been found to really be superconductors.

SCIENCE

# THE SEARCH FOR SUPERCONDUCTORS

Imagine trains that fly above their tracks at airplane speeds and powerful computers that fit in the palm of your hand. Picture unlocking the secrets of the atom, or skiing on slopes made of air. Purely imagination? Not really. All of these things—and more—have been brought closer to reality by the work of Dr. Karl Alex Mueller and Dr. Johannes Georg Bednorz. These two dedicated scientists have changed fantasy to fact through their work with superconductors.

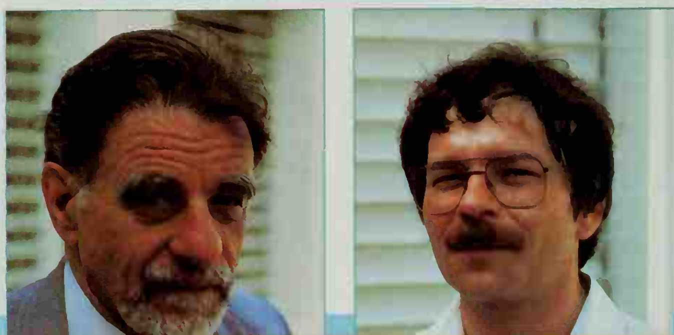
## SEARCHING FOR A BETTER CONDUCTOR

Much of our electricity runs through copper wire. Copper is an example of a conductor, or a material that carries electricity well. However, copper is not a perfect conductor because it offers resistance to the flow of electricity. As a result of resistance, about 15 percent of the electric power passing through a copper wire is wasted as heat.

A superconductor has no resistance. Therefore, it can conduct electricity without any loss of power. With superconductors, power plants could produce more usable electricity at lower costs and with no waste. Electric motors could be made smaller and more powerful. Superconducting wires connecting computer chips could produce smaller, faster computers.

Scientists have known about superconductors for more than 75 years. But although the principle of superconductivity was understood, the method of creating one remained a secret . . . a secret that seemed to be "locked in a deep freeze." For until the time of Mueller and Bednorz's discovery, materials would not become superconductors unless they were chilled to at least −250°C!

Superconductivity pioneers Karl Mueller (left) and Johannes Bednorz.





## TEACHING STRATEGY: ADVENTURE

### FOCUS/MOTIVATION

Display a copy of the periodic table.

• **Where on the periodic table are metallic elements found?** (To the left of the zigzag line that appears on the right side of the table.)

• **Where are nonmetallic elements found?** (To the right of the zigzag line.)

### CONTENT DEVELOPMENT

Remind students that one of the properties of metals is the ability to conduct heat and electricity.

Go on to explain that an electrical conductor is defined more precisely as a material that permits electrical charges to move easily. Emphasize that at normal temperatures, no metal is a perfect conductor; some resistance still impedes the flow of electric charge.

• **What happens to the electrical energy that is blocked by resistance as it flows through a wire?** (It changes into heat energy.)

Point out that this is why wires and other current-carrying devices often feel hot—the electricity impeded by resistance is lost as heat.

Continue the discussion by asking students the following questions:

• **How is a superconductor different from an ordinary conductor of electric-**

To cool materials to such extremely low temperatures, scientists had to use liquid helium, which is very costly. The supercold superconductors were just too expensive to be of general use.

If a substance could become superconducting at –196°C or higher, then it could be cooled with liquid nitrogen. Liquid nitrogen costs as little as a nickel a liter—less expensive than milk or soda. But what substances might become superconductors at these relatively high temperatures? That was the problem Dr. Mueller and Dr. Bednorz had to solve.

▲ **This magnetic disk may seem to be defying gravity. Actually, it is floating above a disk made of a superconductive material. The superconductive disk repels magnetic fields and causes the magnet to float in midair.**

## LOOKING IN A NEW DIRECTION

Many experts thought that superconductors simply did not exist at temperatures higher than –250°C. But Dr. Mueller, a highly respected physicist at IBM's research laboratory in Zurich, Switzerland, remained fascinated by high-temperature superconductors. In fact, he had already devised a new approach to finding one!

To some, his idea seemed impossible. But Dr. Mueller and his partner Dr. Bednorz were willing to follow their unusual approach under the guidance of what Dr. Mueller describes as "my intuition."

For almost three years, the two scientists mixed powders, baked them in ovens to form new compounds, and then chilled them to see if they would lose their resistance to electricity. And for three years, the two scientists kept their work a secret. "We were sure anybody would say, 'These guys are crazy,'" Dr. Bednorz later said. But despite endless hours of hard work and dedication, none of the new compounds was the superconductor Mueller and Bednorz sought.

Then in December 1985, Dr. Bednorz read about a new copper oxide. He and Dr. Mueller thought the oxide looked promising. They decided to test it for superconductivity. On January 27, 1986, Dr. Mueller and Dr. Bednorz broke the temperature barrier to superconductivity—and broke it by a large amount. They achieved superconductivity at –243°C. By April, Mueller and Bednorz had raised the temperature of superconductivity to a new record, –238°C. Around the world, scientists began to duplicate the experiments and make even greater advances in high-temperature superconductors.

In February 1987, a team of researchers at the University of Houston led by Dr. C.W. Chu created a new oxide that shows superconductivity at –175°C. This is the first superconductor that can be cooled with liquid nitrogen—the first superconductor that might be used for everyday purposes.

Dr. Mueller and Dr. Bednorz received the 1987 Nobel Prize for Physics for their pioneering work on superconductors. Their work, however, does not end here. They look forward to the development of a room-temperature superconductor!



### Additional Questions and Topic Suggestions

**1.** Under normal conditions, materials that conduct electricity also conduct heat. Use reference sources to find out how superconductivity affects a material's ability to conduct heat. (Scientists have found that materials in superconductive state generally have less ability to conduct heat than usual and that at very low temperatures, the ability to conduct heat approaches zero. This is contrary to what happens in the nonsuperconductive state, in which high electrical conductivity is accompanied by a high heat conductivity.)

**2.** Find out which elements are superconductors. Then make a copy of the periodic table found in the textbook. Using colored pencils, shade in the elements that are superconductors.

**3.** Find out about the research on superconductivity done in 1933 by W. Meissner and R. Ochsenfeld. Also find out what aspect of superconductivity is referred to as the Meissner Effect.

### Critical Thinking Questions

**1.** Why do you think superconductivity occurs at such low temperatures? (Accept all logical answers. Relevant to the question may be the fact that 0°K, or absolute zero, is the temperature at which all molecular motion ceases.)

**2.** What would be some advantages of a superconductor that could function at room temperature? (Accept all logical answers.)

**ity?** (A superconductor has no resistance.)

- **What is the advantage of this?** (No electrical energy is lost as heat, which makes the conductor much more efficient.)
- **Are superconductors made of the same materials as ordinary conductors?** (Yes.)
- **What must be done to an ordinary conductor in order to make it a superconductor?** (It must be cooled to a very low temperature.)

Explain that the first superconductor to be discovered was mercury, followed shortly thereafter by lead and tin. Now scientists have found at least 36 elements that are superconductors and thousands of alloys and compounds.

### INDEPENDENT PRACTICE

▶ *Activity Book*

After students have read the Science Gazette article, you may want to hand out the reading skills worksheet based on the article in the *Activity Book*.

## ISSUES IN SCIENCE

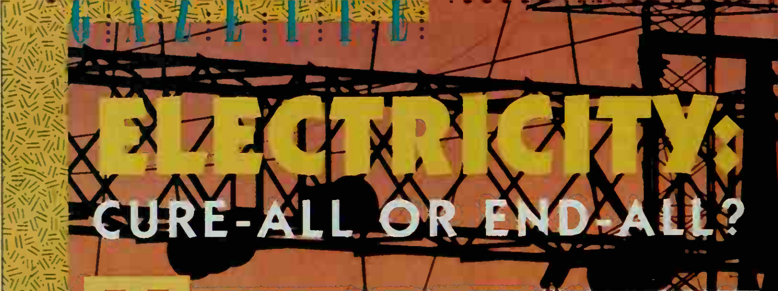
### ELECTRICITY: CURE-ALL OR END-ALL?

**Background Information**

Since Nancy Wertheimer published her study on the possible link between exposure to electromagnetic waves and cancer in 1979, a large number of researchers have also studied the possible link. Most studies show that there is a correlation between exposure to extremely low frequency fields of electromagnetic waves and particular cancers such as leukemia and brain cancer. Some correlation may exist between the incidence of miscarriages or the birth of babies with abnormalities and exposure to the electromagnetic waves by pregnant women. None of the studies shows a cause-and-effect link. It seems likely that electromagnetic waves do have a biological effect, but researchers have not identified what the effect is. There is no conclusive evidence available that the effect is harmful to health. Some researchers suggest that the waves may reduce the amount of melatonin, a hormone that may prevent the growth of some cancers.

The possible correlation between cancer and exposure to electromagnetic waves from electrical wires and electrical appliances has caused concern among the public. Parents of students at one Florida school have sued the school district to close the school because it is near power lines. A Houston school district forced a utility company to remove lines that ran close to schools in the district. Citizens can take precautions that help to reduce exposure to electromagnetic waves given off by appliances. They can sit at least 3 feet from their televisions; they can keep their clock radios and other appliances at least a few feet from their heads when they are sleeping.





# ELECTRICITY: CURE-ALL OR END-ALL?

You have probably read or heard the story about Benjamin Franklin's discovery of electricity during a lightning storm. In the midst of a downpour, he and his son flew a kite with a key attached to the string. The shock they received by touching the key proved that the lightning's charge was conducted through the string and into the metal key. But could Franklin have imagined the impact of his discovery? The modern world of electric appliances, computers, stereos, washing machines, air conditioners, heaters, and more has been built upon his insight. In fact, much of society has come to rely on electricity for most of its needs. Electricity seems like the perfect symbol of technology—the answer to every modern need. Or is it?

In recent years, an increasing number of scientific reports suggest that electric current may have harmful biological effects. It is not the danger of the electric current itself that has people worried. Rather, it is the electromagnetic fields produced by certain levels of electric current in sources such as power lines, household wiring, and electric appliances. Such emissions are referred to as electromagnetic radiation. In particular, there are suggestions that there is a link between exposure to these electromagnetic fields and incidents of cancer.

A connection between high levels of electromagnetic radiation and harmful biological effects has been recognized for quite some time. But long-term exposure to levels of such high intensity are rare. Concern over the dangers caused by low levels of electromagnetic radiation, which began in the late 1970s, created new fears. Virtually all industrialized populations are commonly exposed to such levels of electromagnetic radiation.

The subject came under close scrutiny when Nancy Wertheimer, an epidemiologist (scientist who studies diseases), set out to study the homes of children who had died from cancer in a Colorado neighborhood in order to establish some connection. To her surprise, she found a statistical connection between childhood cancers and exposure to high-current power lines.

Wertheimer's work heralded a series of investigations and a bitter controversy. A similar study in the Colorado area supported her general conclusions, as did another study conducted in Europe. Several other research projects went on to show that workers regularly exposed to strong electromagnetic fields—electricians, power-station operators, telephone line workers—developed and died from leukemia, brain cancer, and brain tumors at significantly higher rates than workers in other fields. These studies also suggested a link between exposure to electromagnetic fields and low-grade illnesses such as fatigue, headaches, drowsiness, and nausea. Additional studies showed a link between the use of electric blankets and miscarriages (lost pregnancies).



## TEACHING STRATEGY: ISSUE

### FOCUS/MOTIVATION

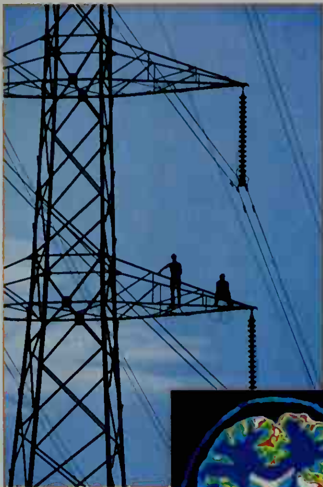
Display a variety of electrical appliances, such as electrical blankets, televisions, hair dryers, toasters, and can openers, or pictures of them.

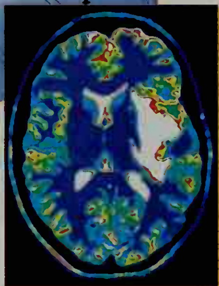
- **What do these have in common?** (All are operated with electricity.)
- **Are there any dangers associated with the use of these appliances?** (Most students will be aware that the operation of these appliances near water is dangerous; few will be aware of the possible dangers from electromagnetic radiation that the appliances give off.)

After reading the title of the Gazette article, ask students what they think the article is about.

The electromagnetic fields in the area surrounding these high-voltage power lines are strong enough to light the fluorescent bulbs.

▼ Prolonged exposure to electromagnetic fields, a hazard of certain jobs, may be related to a high incidence of brain tumors. The gamma image shows a brain with a tumor.





Some of these studies and their related legal battles have prompted electric companies to reroute their wiring and change the location of their transformers. Often, however, cases regarding electromagnetic radiation hazards have been dismissed or postponed due to lack of clear evidence. Despite the seriousness of the issues, the research found to date does not prove a clear, direct link between electromagnetic radiation and cancer. For this reason such findings have not convinced everyone in the scientific and medical communities, the nation's courts, or those in industry of the possible dangers of electromagnetic fields. Skeptical researchers and judges complain that the studies lack scientific foundations, and that they show only a statistical link. Critics say that they need to see actual proof of a cause-and-effect relationship between the electromagnetic fields and illness.

To meet the skeptics' challenges, scientists are trying to show how electromagnetic fields actually affect and harm human cells. Researchers have found that exposure to electromagnetic fields actually promotes faster growth of cancer cells that are more resistant to anticancer drugs. Other studies indicate that exposure to electromagnetic fields inhibits human production of melatonin, a cancer-inhibiting hormone.

In addition, scientists are also trying to discover the actual mechanisms by which



### Additional Questions and Topic Suggestions

**1.** Louis Slesin publishes the *Microwave News*, a bimonthly newsletter that reports stories on electromagnetism. If possible, obtain a copy of an issue. Based on the articles, what do you think is Slesin's position in the controversy?

**2.** If a correlation between cancer and electromagnetic waves is proved, what do you think should be done? How might our lifestyles be changed?

**3.** Research information about electromagnetic waves. What are they? What is the difference between extremely low frequency fields and very low frequency fields?

**4.** Find out what position the Environmental Protection Agency has taken on the controversy by writing for information from the agency or by researching magazine articles in a library.

### CONTENT DEVELOPMENT

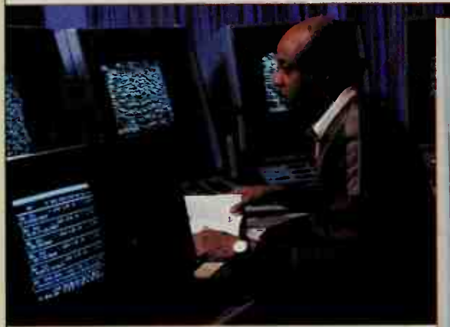
Have students list the electrical appliances that they and their families use during a typical day. After the list is compiled, tell students that all electrical appliances and electrical wires emit an electromagnetic field of radiation. In the past, there was no concern about possible risk from exposure to the electromagnetic field emitted by appliances and high wires. Beginning, however, with a late 1970s study of children in Colorado who developed cancer, an alarm was sounded. Children exposed to electromagnetic fields because of the location near power lines were developing cancer at about 2.5 times the rate of other children. The study indicated a correlation between incidence of childhood cancer and exposure to electromagnetic fields.

Since the initial study, conducted by Nancy Wertheimer, other studies have supported the findings and have linked the incidence of certain diseases and problem pregnancies to electromagnetic fields. The studies, however, do not show a cause-and-effect relationship. Some scientists claim that the incidents are coincidental; others suggest that the research data cannot be attributed to coincidence. The issue continues to be debated, and researchers are still trying to find out whether or not electromagnetic fields are responsible for harmful effects on human biology.

### Class Debate

Numerous research studies have not proven that the effects of exposure to electromagnetic waves are harmful. Research money is limited, and research studies are time consuming. Have students consider other research needs, for example, finding cures for diseases such as cancer and multiple sclerosis. Then have students debate whether research money should be allocated for continued research on the effects of exposure to electromagnetic waves or not.





◄ ▲ **Low-level electromagnetic fields are created by common electrical devices such as hair dryers, electric blankets, and computers. Whether or not these fields are dangerous is yet to be proven.**

electromagnetic fields do their damage. They are focusing on the effect of electromagnetic fields on the flow of ions into and out of cells. Some experiments have shown that the fields may resonate (vibrate at the same frequency) with ions already present in the cell. Such vibration causes the valuable ions to pass through the membrane at an increased rate, thus leaving the cell too quickly and possibly damaging the cell membrane. Other research suggests that under certain conditions, the interaction of the Earth's magnetic field with unnatural electromagnetic fields may knock ions in the cell membrane out of place. This disrupts cell functioning, perhaps leading to illness.

The controversy over the safety or threat of electromagnetic radiation becomes increasingly serious as time goes on and society relies more and more on electric components that produce electromagnetic radiation. Until answers and resolutions to the problem are found, we shall continue to use and rely on electricity to assist and enhance our lives. And in one sense, we shall continue to be human guinea pigs in an unresolved scientific experiment.



## ISSUE (continued)

### ENRICHMENT

Much of the research being conducted about the possible detrimental effects of exposure to electromagnetic fields is sponsored or conducted by the Electric Power Research Institute, an agency funded by the nation's utility companies. Ask students to consider whether the association with the utility companies may bias the findings of the institute.

### CONTENT DEVELOPMENT

Although it has not been established that exposure to electromagnetic fields is dangerous to humans, many people recommend that certain precautions be taken. For example, some people recommend that people reduce their use of electric blankets. They say that the blanket should be used to warm up the bed before you get into it and then turned off. Others say it would be even better if the electric blanket were given up and that people should use quilts or other blankets instead.

- **How else can people minimize exposure to electromagnetic forces?** (Answers will vary.)
- **How might the concern about exposure to electromagnetic waves affect the property values of homes near electrical lines and transmitters?** (Property values may drop because people will be hesitant to buy homes in areas that may present a health risk.)

### INDEPENDENT PRACTICE

▶ *Activity Book*

After students have read the Science Gazette article, you may want to hand out the reading skills worksheet based on the article in the *Activity Book.*

# THE COMPUTER THAT LIVES!

Ronda and her family lived in a space settlement on Pluto. One day, a strong radiation storm swept across the Purple Mountains of their planet. There had been many such storms on the planet in the year 2101. The module in which Ronda and her family lived had been directly in the path of the storm. Somehow, radioactive dust penetrated the sealed glass that served as windows in the module. As a result, Ronda was blind. Radiation had destroyed the nerves that carried the electrical signals from Ronda's eyes to her brain. Her brain could no longer interpret what her eyes were "seeing clearly."

Months after the storm, Ronda sat nervously in a plush armchair in the waiting room of Venus General Hospital. Today was the day the bandages would be removed from her eyes. Ronda was terrified that the operation to restore her sight might have been a failure. She did not want to rely on a seeing-eye robot for the rest of her life.

As the doctors removed the bandages, Ronda thought about the computer that had been implanted in her brain. No larger than a grain of rice, the computer was programmed to record all the images Ronda's eyes picked up and then translate them into messages her brain could understand. The computer was designed to work exactly like the eye nerves that had been destroyed.

The bandages fell from Ronda's eyes. She could see! The living computer inside her head had restored her sight.

## TIME MARCHES ON

Today scientists believe that living computers will be a reality in the not-so-distant future. Living computers, like the one in Ronda's brain, require no outside power source and never need to be replaced. To understand how living computers may be possible, let's look briefly at how computers have evolved since the 1800s.



## FUTURES IN SCIENCE

### THE COMPUTER THAT LIVES!

**Background Information**

Human sight is not made possible by the eyes alone; sight also depends on the vision center in the brain and on the optic nerves that relay images from the eye to the brain. Light enters the pupil of the eye and passes through the lens. An image then forms on the retina, which is at the back of the eye. The retina contains light-sensitive cells that produce nerve impulses that travel along the optic nerves to the vision center of the brain. In the vision center, the images are interpreted, and the person "sees."

When any part of the three components of sight—eye, optic nerves, or vision center—are impaired, the ability to see is lost. The living computer described in the article is taking the place of optic nerves that have been destroyed by radiation.

Relevant to the concept of a living computer is the present-day use of a computer to help a paralyzed girl walk again. In 1983, Dr. Jerrold Petrofsky devised a system in which a high-speed computer delivered tiny shocks to the leg muscles of a girl who had been paralyzed for five years. The computer controlled the firing of impulses in just the right order to make the girl's muscles work; tiny sensing devices on her legs told the computer what the muscles were doing. Dr. Petrofsky hopes someday to make the system small enough to be put inside the human body.

## TEACHING STRATEGY: FUTURE

### FOCUS/MOTIVATION

Begin by asking students the following question:

- **What makes it possible for you to see?** (Answers may vary. Most students will probably say their eyes.)

### CONTENT DEVELOPMENT

Continue the discussion by explaining to students that sight is not made possible by the eyes alone; the eyes can only pick up images. In order for a person to see, the images formed at the back of the eye (on a part of the eye called the retina) must be relayed to the vision center of the brain via optic nerves. The images are interpreted in the vision center, and the person "sees."

- **According to the article, what part of the sight process was disrupted for Ronda?** (The part in which images are relayed to the brain.)
- **Why could images from Ronda's eyes no longer be transmitted to the brain?** (Her optic nerves had been destroyed.)
- **What made it possible for Ronda to see again?** (A tiny computer that could function as optic nerves was implanted in her brain.)

## Additional Questions and Topic Suggestions

1. Space colonies may be a lifestyle option in the future. Does this story make you want to live in a space colony? Why or why not? (Accept all answers. Some students may be wary of radiation storms that could cause blindness; others may be intrigued by the possibility of traveling to other planets and living in a strange world.)
2. Find out more about ways in which bacteria break down substances. Two topics that you might research include the importance of bacteria in soil and the role of bacteria in foods such as yogurt.
3. Why might creative thinking and reasoning ability be possible with a "living computer"? (Accept all answers. A logical answer is that because reasoning and creative thinking are functions of humans, a computer made of living substances might more closely resemble the human brain.)

Vacuum tubes like these made the first computers possible.

The computers of the 1950s used transistors instead of vacuum tubes.

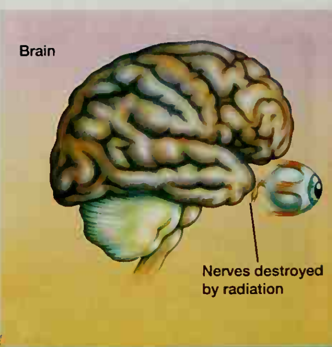
The first computers, made up of clunky gears and wheels, were turned by hand. They had only the simplest ability to answer questions based on the information stored inside them. By 1950, computers were run by electricity and operated with switches instead of gears. Information was stored when thousands of switches turned on and off in certain ways. While a lot of information could be fed into electrical memory banks, the computers of the 1950s were still very crude. In fact, the typical 1950s computer took up an entire room and could do less than many video-arcade games of the 1980s.

The computers of the 1980s contain thousands of switches and can be placed on a tabletop. The reason for the compactness of these computers is the silicon chip. Engineers can put hundreds of switches on a tiny piece of the chemical silicon. These tiny pieces of silicon, known as chips, are manufactured using laser beams and microscopes. It is these chips that record the information when, for example, you tell a computer your name.

But even with the silicon chip, modern computers cannot really think creatively or reason. And a computer has less sense than an ordinary garden snail. Experts feel that in order for computers to "graduate" to higher-level tasks, a whole new way must be developed of storing information in them. The key to developing a new system of information storage may lie in molecules of certain chemicals.

Why molecules? Scientists know that when some molecules are brought together, interesting changes take place. For example, electricity can jump from one molecule to another almost as if tiny switches were being shut on and off between them. Can we learn how to work these tiny switches? If so, then perhaps a whole new type of computer could be built!

This new computer might be able to hold more information in a single drop of liquid




When nerves connecting the eye to the brain are destroyed, no electrical signals can be carried. A person cannot see. By implanting a computer the size of a grain of rice, the person's sight is restored. The computer is designed to work exactly like the eye nerves.



### FUTURE (continued)

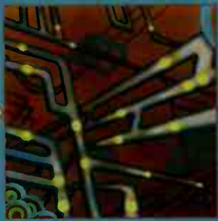
**ENRICHMENT**

• **What aspect of this article lets you know immediately that the story takes place in the future?** (Ronda and her family live in a space settlement on Pluto.)

Point out to students that someday travel to outer space may be quite commonplace and that people may actually be able to live in space or on other planets.

Divide the class into small groups. Challenge each group to imagine what life would be like in a space settlement such as the one described in the article. Have the groups translate their ideas into dramatizations to share with the class.

▲ Today, thousands of transistors are packed onto a silicon chip.



▲ A complex network of protein molecules, such as the one in this drawing, may be the electrical switches in computers of the future.

than today's computer could store in an entire roomful of chips. As you can imagine, the molecules in this computer of the future would have to be pretty special. And they would have to be produced in a new way.

## LEAVE IT TO BACTERIA

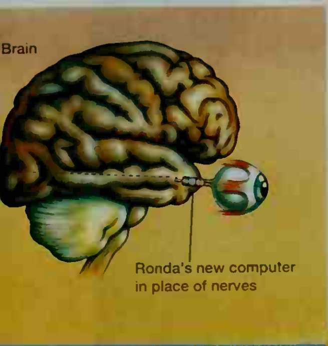
One of the most popular current ideas concerning how these molecules could be produced is: Let bacteria do it for us! Bacteria are all around us. They constantly break down very complicated chemicals into molecules. Bacteria are at work in our bodies, in our food, and in our environment every minute of every day. Some scientists feel that bacteria can be "taught" to make special molecules. These molecules, when mixed together, could produce the flow of electricity needed to make a computer.

Of course, bacteria cannot be taught in the same sense that people can. Bacteria are not able to "learn." However, scientists can now control bacteria in many unusual ways. There are new techniques available that allow scientists to combine two different types of bacteria to produce a third, totally different, type. In the future, bacteria may produce chemicals that have never been seen before.

In terms of a living computer, imagine that some bacteria have been taught to make special molecules. These bacteria could be grown in a special container and fed a particular substance to produce certain molecules. If the molecules could be told, or programmed, to do the right things, you would have a computer. And the computer would actually be alive because the bacteria would live, grow, and produce molecules inside their container.

Think about the living computer implanted in Ronda's brain, which allowed her to see again. Remember that bacteria need food to make molecules. Suppose that the computer in Ronda's brain was fed by her own blood, like all the other cells in her body. If this were the case, Ronda's computer would live as long as Ronda herself.

It may be many years before the living computer becomes a reality. Scientists must learn more about such things as how molecules react together and how they can be programmed. But many scientists await the day when they can look at a computer and say, "It's alive."






### Critical Thinking Questions

**1.** What aspect of this story lets you know that in the future, interplanetary travel will be a normal activity? (Ronda, who lives on Pluto, goes to a hospital on Venus for treatment.)

**2.** Do you think the author of this story was being totally realistic in letting Ronda's blindness be the only result of the radiation storm that swept across the space colony? Why or why not? (Answers may vary. Some students may realize that radiation contamination usually causes extensive and long-term damage; it can cause many other physical impairments and even death. The story is also somewhat unrealistic because no mention is made of the damage caused to other members of Ronda's family or of the long-term effects of radiation contamination on the space colony.)

**3.** What possible hazards can be associated with the area of implanting a computer in the human brain? (Answers may vary. An obvious answer is the possibility of the body's rejecting a foreign substance.)

### GUIDED PRACTICE

**Skills Development**

***Skill: Making diagrams***

Have students make creative diagrams to show how computers have changed in size since the 1800s. Have students include the tiny computer described in this article as part of the diagram. Students may wish to do additional research to find out more about the actual appearance and dimensions of the computers that are described in this article.

### ENRICHMENT

Encourage interested students to study the mechanisms of other physiological functions, such as digestion, hearing, and locomotion. Challenge students to consider how living computers might be able to restore these functions if they should become impaired.

### INDEPENDENT PRACTICE

▶ *Activity Book*

After students have read the Science Gazette article, you may want to hand out the reading skills worksheet based on the article in the *Activity Book*.

# For Further Reading

If you have been intrigued by the concepts examined in this textbook, you may also be interested in the ways fellow thinkers—novelists, poets, essayists, as well as scientists—have imaginatively explored the same ideas.


**Chapter 1:** Electric Charges and Currents

Cosner, Sharon. *The Light Bulb: Inventions that Changed Our Lives.* New York: Walker.

Franklin, Benjamin. *Autobiography of Benjamin Franklin.* New York: Airmont.

Shelley, Mary. *Frankenstein.* London, England: Penguin.

Silverstein, Shel. *A Light in the Attic.* New York: Harper & Row.

**Chapter 2:** Magnetism

Averons, Pierre. *The Atom.* New York: Barron.

Clark, Electra. *Robert Peary: Boy of the North Pole.* New York: Macmillan.

Clarke, Arthur C. *The Wind from the Sun: Stories of the Space Age.* New York: New American Library.

Mason, Theodore K. *Two Against the Ice: Amundsen and Ellsworth.* Spring Valley, NY: Dodd, Mead.

Vogt, Gregory. *Electricity and Magnetism.* New York: Watts.

**Chapter 3:** Electromagnetism

Ellis, Ella T. *Riptide.* New York: Macmillan.

Evans, Arthur N. *The Automobile.* Minneapolis, MN: Lerner Publications.

Farr, Naunerle C. *Thomas Edison—Alexander Graham Bell.* West Haven, CT: Pendulum Press.

Mazer, Harry. *When the Phone Rang.* New York: Scholastic.

Snow, Dorothea J. *Samuel Morse: Inquisitive Boy.* New York: Macmillan.

**Chapter 4:** Electronics and Computers

Chetwin, Grace. *Out of the Dark World.* New York: Lothrop, Lee & Shepard Books.

Clarke, Arthur C. *2001: A Space Odyssey.* New York: New American Library.

Francis, Dorothy. *Computer Crime.* New York: Lodestar.

Trainer, David. *A Day in the Life of a TV News Reporter.* Mahwah, NJ: Troll.


# Appendix A



The metric system of measurement is used by scientists throughout the world. It is based on units of ten. Each unit is ten times larger or ten times smaller than the next unit. The most commonly used units of the metric system are given below. After you have finished reading about the metric system, try to put it to use. How tall are you in metrics? What is your mass? What is your normal body temperature in degrees Celsius?

## Commonly Used Metric Units

**Length** The distance from one point to another

| | |
|---|---|
| meter (m) | A meter is slightly longer than a yard.<br>1 meter = 1000 millimeters (mm)<br>1 meter = 100 centimeters (cm)<br>1000 meters = 1 kilometer (km) |

**Volume** The amount of space an object takes up

| | |
|---|---|
| liter (L) | A liter is slightly more than a quart.<br>1 liter = 1000 milliliters (mL) |

**Mass** The amount of matter in an object

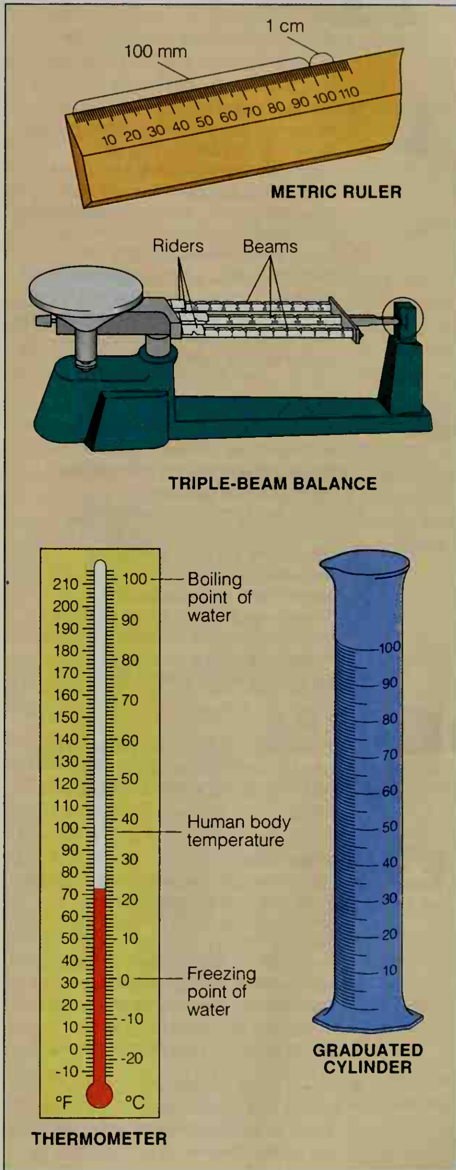
| | |
|---|---|
| gram (g) | A gram has a mass equal to about one paper clip.<br>1000 grams = 1 kilogram (kg) |

**Temperature** The measure of hotness or coldness

| | |
|---|---|
| degrees Celsius (°C) | 0°C = freezing point of water<br>100°C = boiling point of water |

## Metric–English Equivalents

2.54 centimeters (cm) = 1 inch (in.)
1 meter (m) = 39.37 inches (in.)
1 kilometer (km) = 0.62 miles (mi)
1 liter (L) = 1.06 quarts (qt)
250 milliliters (mL) = 1 cup (c)
1 kilogram (kg) = 2.2 pounds (lb)
28.3 grams (g) = 1 ounce (oz)
$°C = 5/9 \times (°F - 32)$



# Appendix B

# LABORATORY SAFETY
## Rules and Symbols

### Glassware Safety

1. Whenever you see this symbol, you will know that you are working with glassware that can easily be broken. Take particular care to handle such glassware safely. And never use broken or chipped glassware.
2. Never heat glassware that is not thoroughly dry. Never pick up any glassware unless you are sure it is not hot. If it is hot, use heat-resistant gloves.
3. Always clean glassware thoroughly before putting it away.

### Fire Safety

1. Whenever you see this symbol, you will know that you are working with fire. Never use any source of fire without wearing safety goggles.
2. Never heat anything—particularly chemicals—unless instructed to do so.
3. Never heat anything in a closed container.
4. Never reach across a flame.
5. Always use a clamp, tongs, or heat-resistant gloves to handle hot objects.
6. Always maintain a clean work area, particularly when using a flame.

### Heat Safety

Whenever you see this symbol, you will know that you should put on heat-resistant gloves to avoid burning your hands.

### Chemical Safety

1. Whenever you see this symbol, you will know that you are working with chemicals that could be hazardous.
2. Never smell any chemical directly from its container. Always use your hand to waft some of the odors from the top of the container toward your nose—and only when instructed to do so.
3. Never mix chemicals unless instructed to do so.
4. Never touch or taste any chemical unless instructed to do so.
5. Keep all lids closed when chemicals are not in use. Dispose of all chemicals as instructed by your teacher.
6. Immediately rinse with water any chemicals, particularly acids, that get on your skin and clothes. Then notify your teacher.

### Eye and Face Safety

1. Whenever you see this symbol, you will know that you are performing an experiment in which you must take precautions to protect your eyes and face by wearing safety goggles.
2. When you are heating a test tube or bottle, always point it away from you and others. Chemicals can splash or boil out of a heated test tube.

### Sharp Instrument Safety

1. Whenever you see this symbol, you will know that you are working with a sharp instrument.
2. Always use single-edged razors; double-edged razors are too dangerous.
3. Handle any sharp instrument with extreme care. Never cut any material toward you; always cut away from you.
4. Immediately notify your teacher if your skin is cut.

### Electrical Safety

1. Whenever you see this symbol, you will know that you are using electricity in the laboratory.
2. Never use long extension cords to plug in any electrical device. Do not plug too many appliances into one socket or you may overload the socket and cause a fire.
3. Never touch an electrical appliance or outlet with wet hands.

### Animal Safety

1. Whenever you see this symbol, you will know that you are working with live animals.
2. Do not cause pain, discomfort, or injury to an animal.
3. Follow your teacher's directions when handling animals. Wash your hands thoroughly after handling animals or their cages.

# Appendix C

# SCIENCE SAFETY RULES

One of the first things a scientist learns is that working in the laboratory can be an exciting experience. But the laboratory can also be quite dangerous if proper safety rules are not followed at all times. To prepare yourself for a safe year in the laboratory, read over the following safety rules. Then read them a second time. Make sure you understand each rule. If you do not, ask your teacher to explain any rules you are unsure of.

## Dress Code

**1.** Many materials in the laboratory can cause eye injury. To protect yourself from possible injury, wear safety goggles whenever you are working with chemicals, burners, or any substance that might get into your eyes. Never wear contact lenses in the laboratory.

**2.** Wear a laboratory apron or coat whenever you are working with chemicals or heated substances.

**3.** Tie back long hair to keep it away from any chemicals, burners and candles, or other laboratory equipment.

**4.** Remove or tie back any article of clothing or jewelry that can hang down and touch chemicals and flames.

## General Safety Rules

**5.** Read all directions for an experiment several times. Follow the directions exactly as they are written. If you are in doubt about any part of the experiment, ask your teacher for assistance.

**6.** Never perform activities that are not authorized by your teacher. Obtain permission before "experimenting" on your own.

**7.** Never handle any equipment unless you have specific permission.

**8.** Take extreme care not to spill any material in the laboratory. If a spill occurs, immediately ask your teacher about the proper cleanup procedure. Never simply pour chemicals or other substances into the sink or trash container.

**9.** Never eat in the laboratory.

**10.** Wash your hands before and after each experiment.

## First Aid

**11.** Immediately report all accidents, no matter how minor, to your teacher.

**12.** Learn what to do in case of specific accidents, such as getting acid in your eyes or on your skin. (Rinse acids from your body with lots of water.)

**13.** Become aware of the location of the first-aid kit. But your teacher should administer any required first aid due to injury. Or your teacher may send you to the school nurse or call a physician.

**14.** Know where and how to report an accident or fire. Find out the location of the fire extinguisher, phone, and fire alarm. Keep a list of important phone numbers—such as the fire department and the school nurse—near the phone. Immediately report any fires to your teacher.

## Heating and Fire Safety

**15.** Again, never use a heat source, such as a candle or burner, without wearing safety goggles.

**16.** Never heat a chemical you are not instructed to heat. A chemical that is harmless when cool may be dangerous when heated.

**17.** Maintain a clean work area and keep all materials away from flames.

**18.** Never reach across a flame.

**19.** Make sure you know how to light a Bunsen burner. (Your teacher will demonstrate the proper procedure for lighting a burner.) If the flame leaps out of a burner toward you, immediately turn off the gas. Do not touch the burner. It may be hot. And never leave a lighted burner unattended!

**20.** When heating a test tube or bottle, always point it away from you and others. Chemicals can splash or boil out of a heated test tube.

**21.** Never heat a liquid in a closed container. The expanding gases produced may blow the container apart, injuring you or others.

22. Before picking up a container that has been heated, first hold the back of your hand near it. If you can feel the heat on the back of your hand, the container may be too hot to handle. Use a clamp or tongs when handling hot containers.

## Using Chemicals Safely

23. Never mix chemicals for the "fun of it." You might produce a dangerous, possibly explosive substance.

24. Never touch, taste, or smell a chemical unless you are instructed by your teacher to do so. Many chemicals are poisonous. If you are instructed to note the fumes in an experiment, gently wave your hand over the opening of a container and direct the fumes toward your nose. Do not inhale the fumes directly from the container.

25. Use only those chemicals needed in the activity. Keep all lids closed when a chemical is not being used. Notify your teacher whenever chemicals are spilled.

26. Dispose of all chemicals as instructed by your teacher. To avoid contamination, never return chemicals to their original containers.

27. Be extra careful when working with acids or bases. Pour such chemicals over the sink, not over your workbench.

28. When diluting an acid, pour the acid into water. Never pour water into an acid.

29. Immediately rinse with water any acids that get on your skin or clothing. Then notify your teacher of any acid spill.

## Using Glassware Safely

30. Never force glass tubing into a rubber stopper. A turning motion and lubricant will be helpful when inserting glass tubing into rubber stoppers or rubber tubing. Your teacher will demonstrate the proper way to insert glass tubing.

31. Never heat glassware that is not thoroughly dry. Use a wire screen to protect glassware from any flame.

32. Keep in mind that hot glassware will not appear hot. Never pick up glassware without first checking to see if it is hot. See #22.

33. If you are instructed to cut glass tubing, fire-polish the ends immediately to remove sharp edges.

34. Never use broken or chipped glassware. If glassware breaks, notify your teacher and dispose of the glassware in the proper trash container.

35. Never eat or drink from laboratory glassware. Thoroughly clean glassware before putting it away.

## Using Sharp Instruments

36. Handle scalpels or razor blades with extreme care. Never cut material toward you; cut away from you.

37. Immediately notify your teacher if you cut your skin when working in the laboratory.

## Animal Safety

38. No experiments that will cause pain, discomfort, or harm to mammals, birds, reptiles, fishes, and amphibians should be done in the classroom or at home.

39. Animals should be handled only if necessary. If an animal is excited or frightened, pregnant, feeding, or with its young, special handling is required.

40. Your teacher will instruct you as to how to handle each animal species that may be brought into the classroom.

41. Clean your hands thoroughly after handling animals or the cage containing animals.

## End-of-Experiment Rules

42. After an experiment has been completed, clean up your work area and return all equipment to its proper place.

43. Wash your hands after every experiment.

44. Turn off all burners before leaving the laboratory. Check that the gas line leading to the burner is off as well.

# Glossary

**alternating current:** current in which the electrons reverse their direction regularly

**amplifier:** device that increases the strength of an electric signal

**atom:** smallest part of an element that has all the properties of that element

**aurora:** glowing region of air caused by solar particles that break through the Earth's magnetic field

**battery:** device that produces electricity by converting chemical energy into electrical energy; made up of electrochemical cells

**binary system:** number system consisting of only two numbers, 0 and 1, that is used by computers

**bit:** single electronic switch, or piece of information

**byte:** string of bits; usually 8 bits make up a byte

**cathode-ray tube:** type of vacuum tube that uses electrons to produce an image on a screen

**central processing unit:** part of a computer that controls the operation of all the other components of the computer

**charge:** physical property of matter that can give rise to an electric force of attraction or repulsion

**chip:** thin piece of silicon containing an integrated circuit

**circuit:** complete path through which electricity can flow

**circuit breaker:** reusable device that protects a circuit from becoming overloaded

**conduction:** method of charging an object by allowing electrons to flow through one object to another object

**conductor:** material which permits electrons to flow freely

**current:** flow of charge

**diode:** vacuum tube or semiconductor that acts as a rectifier

**direct current:** current consisting of electrons that flow constantly in one direction

**disk drive:** part of a computer that can act as an input device by reading information off a disk and entering it into the computer or as an output device removing information from a computer and storing it on a disk

**doping:** process of adding impurities to semiconducting materials

**electric discharge:** loss of static electricity as electric charges move off an object

**electric field:** area over which an electric charge exerts a force

**electric motor:** device that uses an electromagnet to convert electrical energy to mechanical energy that is used to do work

**electromagnet:** solenoid with a magnetic material such as iron inside its coils

**electromagnetic induction:** process by which a current is produced by a changing magnetic field

**electromagnetic wave:** wave made up of a combination of a changing electric field and a changing magnetic field

**electromagnetism:** relationship between electricity and magnetism

**electron:** subatomic particle with a negative charge found in an area outside the nucleus of an atom

**electronics:** study of the release, behavior, and control of electrons as it relates to use in practical devices

**electroscope:** instrument used to detect charge

**force:** push or pull on an object

**friction:** force that opposes motion that is exerted when two objects are rubbed together in some way

**fuse:** thin strip of metal used for safety because when the current flowing through it becomes too high, it melts and breaks the flow of electricity

**galvanometer:** device that uses an electromagnet to detect small amounts of current

**generator:** device that uses electromagnets to convert mechanical energy to electrical energy

**hardware:** physical parts of a computer

**induced current:** current produced in a wire exposed to a changing magnetic field

**induction:** method of charging an object by rearranging its electric charges into groups of positive charge and negative charge

**input device:** device through which data is fed into a computer

**insulator:** material made up of atoms with tightly bound electrons that are not able to flow freely

**integrated circuit:** circuit consisting of many diodes and transistors all placed on a thin piece of silicon, known as a chip

**magnetic domain:** region of a material in which the magnetic fields of individual atoms are aligned

**magnetic field:** area over which the magnetic force is exerted

**magnetism:** force of attraction or repulsion of a magnetic material due to the arrangement of its atoms

**magnetosphere:** region in which the magnetic field of the Earth is found

**main memory:** part of a computer that contains data and operating instructions that are processed by the central processing unit

**modem:** device that changes electronic signals from a computer into messages that can be carried over telephone lines

**neutron:** subatomic particle with no charge located in the nucleus of an atom

**Ohm's law:** expression that relates current, voltage, and resistance: V = I x R

**output device:** part of a computer through which information is removed

**parallel circuit:** circuit in which different parts are on separate branches; if one part does not operate properly, current can still flow through the others

**photocell:** device that uses electrons emitted from a metal during the photoelectric effect to produce current

**pole:** regions of a magnet where the magnetic effects are the strongest

**potential difference:** difference in charge as created by opposite posts of a battery

**power:** rate at which work is done or energy is used

**proton:** subatomic particle located in the nucleus of an atom with a positive charge

**rectifier:** device that converts alternating current to direct current; accomplished by a vacuum tube or semiconductor called a diode

**resistance:** opposition to the flow of electric charge

**semiconductor:** material that is able to conduct electric currents better than insulators but not as well as true conductors

**series circuit:** circuit in which all parts are connected one after another; if one part fails to operate properly, the current cannot flow

**software:** set of instructions, or program, a computer follows

**solenoid:** long coil of wire that acts like a magnet when current flows through it

**solid-state device:** device, consisting of semiconductors, that has come out of the study of the structure of solid materials

**static electricity:** movement of charges from one object to another without further movement

**superconductor:** material in which resistance is essentially zero at certain low temperatures

**thermocouple:** device that produces electrical energy from heat energy

**transformer:** device that increases or decreases the voltage of alternating current

**transistor:** device consisting of three layers of semiconductors used to amplify an electric signal

**triode:** type of vacuum tube used for amplification that consists of a wire grid as well as its electrodes

**vacuum tube:** glass tube, in which almost all gases are removed, which contains electrodes that produce a one-way flow of electrons

**voltage:** potential difference; energy carried by charges that make up a current

# Index

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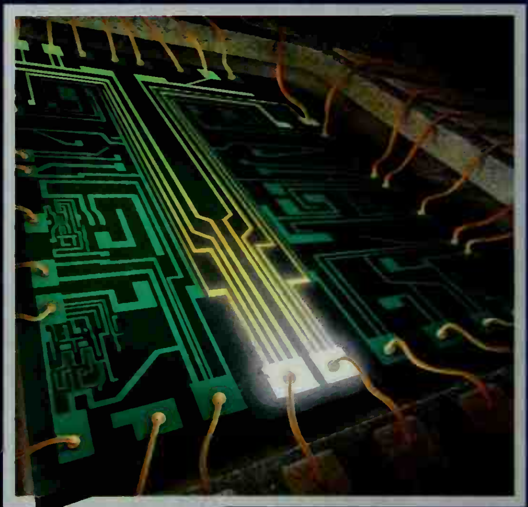
PRENTICE HALL SCIENCE

# ELECTRICITY AND MAGNETISM





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