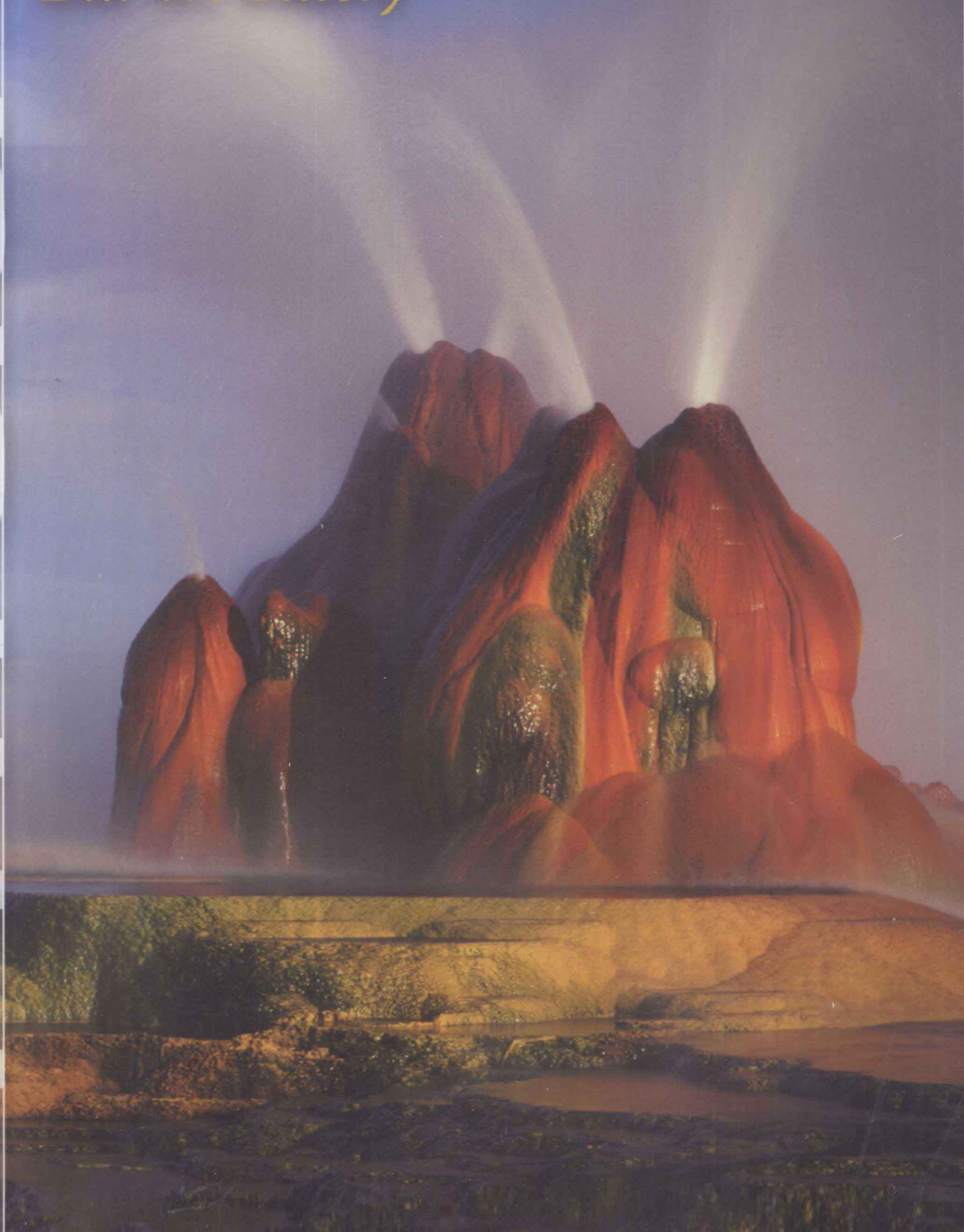
PHYSICAL Science

SIXTH EDITION

Bill W. Tillery



Sixth Edition

Physical Science

Bill W. Tillery
Arizona State University

McGraw Hill **Higher Education**

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Preface

Physical Science is a straightforward, easy-to-read, but substantial introduction to the fundamental behavior of matter and energy. It is intended to serve the needs of nonscience majors who are required to complete one or more physical science courses. It introduces basic concepts and key ideas while providing opportunities for students to learn reasoning skills and a new way of thinking about their environment. No prior work in science is assumed. The language, as well as the mathematics, is as simple as can be practical for a college-level science course.

Organization

The *Physical Science* sequence of chapters is flexible, and the instructor can determine topic sequence and depth of coverage as needed. The materials are also designed to support a conceptual approach, or a combined conceptual and problem-solving approach. With laboratory studies, the text contains enough material for the instructor to select a sequence for a two-semester course. It can also serve as a text in a one-semester astronomy and earth science course, or in other combinations.

> *"The text is excellent. I do not think I could have taught the course using any other textbook. I think one reason I really enjoy teaching this course is because of the text. I could say for sure that this is one of the best textbooks I have seen in my career. . . . I love this textbook for the following reasons: (1) it is comprehensive, (2) it is very well written, (3) it is easily readable and comprehendible, (4) it has good graphics."*
> —Ezat Heydari, Jackson State University

Meeting Student Needs

Physical Science is based on two fundamental assumptions arrived at as the result of years of experience and observation from teaching the course: (a) that students taking the course often have very limited background and/or aptitude in the natural sciences; and (b) that this type of student will better grasp the ideas and principles of physical science if they are discussed with minimal use of technical terminology and detail. In addition, it is critical for the student to see relevant applications of the material to everyday life. Most of these everyday-life applications, such as environmental concerns, are not isolated in an arbitrary chapter; they are discussed where they occur naturally throughout the text.

Each chapter presents historical background where appropriate, uses everyday examples in developing concepts, and follows a logical flow of presentation. The historical chronology, of special interest to the humanistically inclined nonscience major, serves to humanize the science being presented. The use of everyday examples appeals to the nonscience major, typically accustomed to reading narration, not scientific technical writing, and also tends to bring relevancy to the material being presented. The logical flow of presentation is helpful to students not accustomed to thinking about relationships between what is being read and previous knowledge learned, a useful skill in understanding the physical sciences. Worked examples help students to integrate concepts and understand the use of relationships called equations. They also serve as a model for problem solving; consequently, special attention is given to *complete* unit work and to the clear, fully expressed use of mathematics. Where appropriate, chapters contain one or more activities, called Concepts Applied, that use everyday materials rather than specialized laboratory equipment. These activities are intended to bring the science concepts closer to the world of the student. The activities are supplemental and can be done as optional student activities or as demonstrations.

> *"It is more readable than any text I've encountered. This has been my first experience teaching university physical science; I picked up the book and found it very user-friendly. The level of detail is one of this text's greatest strengths. It is well suited for a university course."*
> —Richard M. Woolheater, Southeastern Oklahoma State University

"The author's goals and practical approach to the subject matter is exactly what we are looking for in a textbook. . . . The practical approach to problem solving is very appropriate for this level of student."
—Martha K. Newchurch, Nicholls State University

". . . the book engages minimal use of technical language and scientific detail in presenting ideas. It also uses everyday examples to illustrate a point. This approach bonds with the mindset of the nonscience major who is used to reading prose in relation to daily living."
—Ignatius Okafor, Jarvis Christian College

"I was pleasantly surprised to see that the author has written a textbook that seems well suited to introductory physical science at this level. . . . Physical Science *seems to strike a nice balance between the two—avoiding unnecessary complications while still maintaining a rigorous viewpoint. I prefer a textbook that goes beyond what I am able to cover in class, but not too much. Tillery seems to have done a good job here."*
—T. G. Heil, University of Georgia

New to This Edition

In general, there has been a concerted effort to make the text even more user-friendly and relevant for students:

- A new "Concepts Applied" feature was added throughout the text, adding applications of relevance for students.
- Where needed, Parallel Exercises were reorganized to make Group A and B exercises more physically, as well as conceptually, congruent.
- Then the Parallel Exercises were selectively "tuned" for the intended audience of nonscience majors by revising and replacing some exercises with new, more conceptual exercises.
- Text materials were made more conceptually oriented and student-friendly throughout.
- The overall size of the text was reduced by two chapters through reorganizing and condensing some of the historical background material.
- Old chapter 2, "Motion," and old chapter 3, "Patterns of Motion," were merged into one new chapter ("Motion") for a more intuitive presentation.
- Old chapter 9, "Atomic Structure," was substantially rewritten and merged with old chapter 10, "Elements and the Periodic Table," into one new chapter ("Atoms and Periodic Properties") with a more student-friendly approach.
- Old chapter 13, "Water and Solutions," (new chapter 11) was substantially rewritten to be more conceptual and relevant to students.
- The astronomy chapters were substantially rewritten to be more intuitive, contain less history, and update factual materials.
- To satisfy requests from current users of the text, new "Closer Look" features were added, for example: Freefall, Simple Machines, The Measurement Process, Doppler Radar, Lasers, Radiation and Food Preservation, Three Mile Island and Chernobyl, Dark Energy, Seismic Tomography, Estuary Pollution, and the Health of the Chesapeake Bay.
- Also to satisfy requests from current users of the text, additional "People Behind the Science" features were added, including biographies on Isaac Newton, Michael Faraday, Erwin Schrödinger, Robert Bunsen, Shirley Ann Jackson, Stephen Hawking, Jocelyn (Susan) Bell Burnell, and Carl Sagan.

The Learning System

Physical Science has an effective combination of innovative learning aids intended to make the student's study of science more effective and enjoyable. This variety of aids is included to help students clearly understand the concepts and principles that serve as the foundation of the physical sciences.

Overview

Chapter 1 provides an *overview* or orientation to what the study of physical science in general, and this text in particular, are all about. It discusses the fundamental methods and techniques used by scientists to study and understand the world around us. It also explains the problem-solving approach used throughout the text so that students can more effectively apply what they have learned.

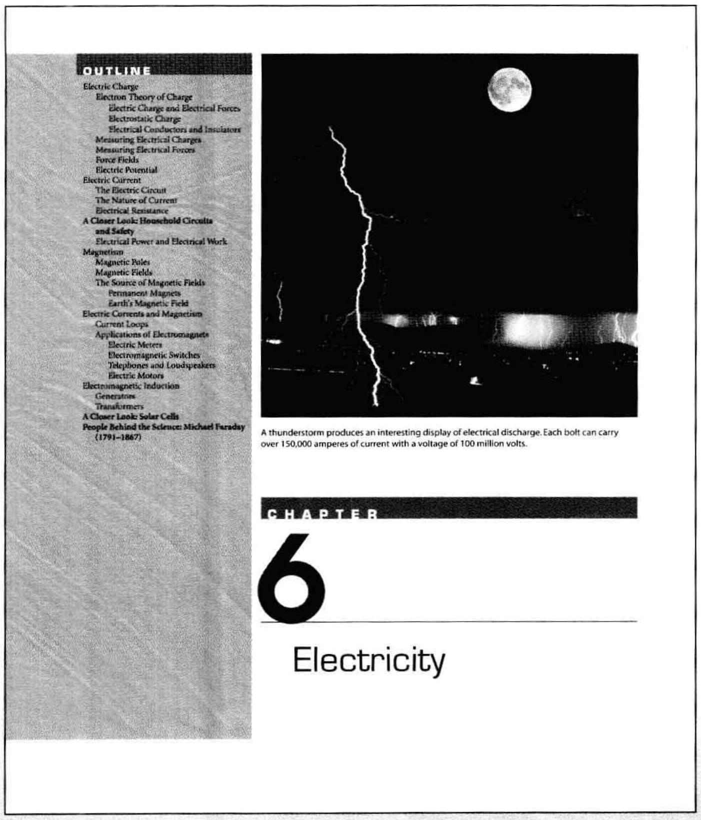
Chapter Opening Tools

Chapter Outline

The chapter outline includes all the major topic headings and subheadings within the body of the chapter. It gives you a quick glimpse of the chapter's contents and helps you locate sections dealing with particular topics.

Chapter Overview

Each chapter begins with an introductory overview. The overview previews the chapter's contents and what you can expect to learn from reading the chapter. It adds to the general outline of the chapter by introducing you to the concepts to be covered, facilitating in the integration of topics, and helping you to stay focused and organized while reading the chapter for the first time. After reading the introduction, browse through the chapter, paying particular attention to the topic headings and illustrations so that you get a feel for the kinds of ideas included within the chapter.



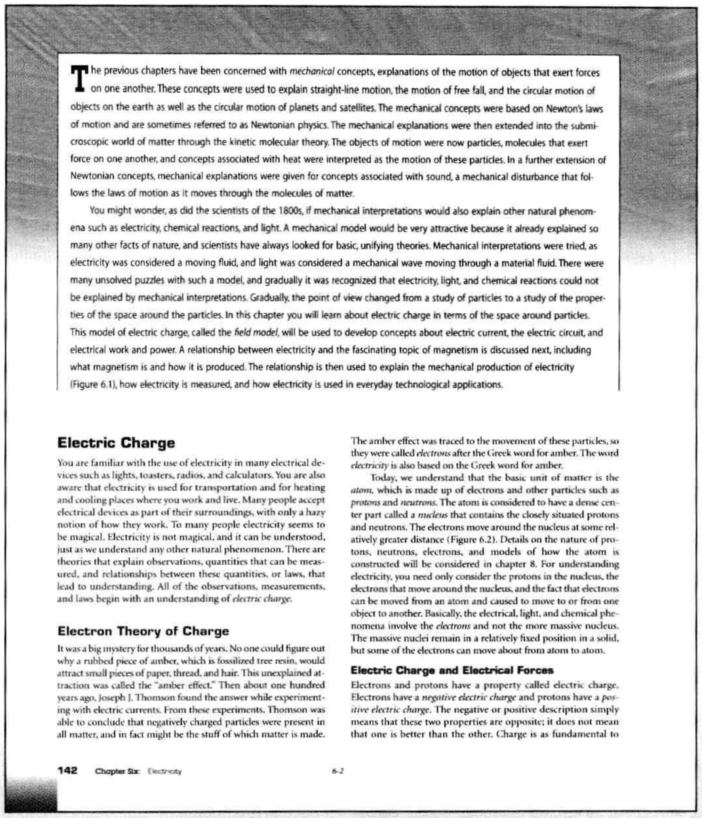
OUTLINE

A thunderstorm produces an interesting display of electrical discharge. Each bolt can carry over 150,000 amperes of current with a voltage of 100 million volts.

CHAPTER

6

Electricity



The previous chapters have been concerned with *mechanical* concepts, explanations of the motion of objects that exert forces on one another. These concepts were used to explain straight-line motion, the motion of free fall, and the circular motion of objects on the earth as well as the circular motion of planets and satellites. The mechanical concepts were based on Newton's laws of motion and are sometimes referred to as Newtonian physics. The mechanical explanations were then extended into the submicroscopic world of matter through the kinetic molecular theory. The objects of motion were now particles, molecules that exert force on one another, and concepts associated with heat were interpreted as the motion of these particles. In a further extension of Newtonian concepts, mechanical explanations were given for concepts associated with sound, a mechanical disturbance that follows the laws of motion as it moves through the molecules of matter.

You might wonder, as did the scientists of the 1800s, if mechanical interpretations would also explain other natural phenomena such as electricity, chemical reactions, and light. A mechanical model would be very attractive because it already explained so many other facts of nature, and scientists have always looked for basic, unifying theories. Mechanical interpretations were tried, as electricity was considered a moving fluid, and light was considered a mechanical wave moving through a material fluid. There were many unsolved puzzles with such a model, and gradually it was recognized that electricity, light, and chemical reactions could not be explained by mechanical interpretations. Gradually, the point of view changed from a study of particles to a study of the properties of the space around the particles. In this chapter you will learn about electric charge in terms of the space around particles. This model of electric charge, called the *field model*, will be used to develop concepts about electric current, the electric circuit, and electrical work and power. A relationship between electricity and the fascinating topic of magnetism is discussed next, including what magnetism is and how it is produced. The relationship is then used to explain the mechanical production of electricity (Figure 6.1), how electricity is measured, and how electricity is used in everyday technological applications.

Electric Charge

You are familiar with the use of electricity in many electrical devices such as lights, toasters, radios, and calculators. You are also aware that electricity is used for transportation and for heating and cooling places where you work and live. Many people accept electrical devices as part of their surroundings, with only a hazy notion of how they work. To many people electricity seems to be magical. Electricity is not magical, and it can be understood, just as we understand any other natural phenomenon. There are theories that explain observations, quantities that can be measured, and relationships between these quantities, or laws, that lead to understanding. All of the observations, measurements, and laws begin with an understanding of *electric charge*.

Electron Theory of Charge

It was a big mystery for thousands of years. No one could figure out why a rubbed piece of amber, which is fossilized tree resin, would attract small pieces of paper, thread, and hair. This unexplained attraction was called the "amber effect." Then about one hundred years ago, Joseph J. Thomson found the answer while experimenting with electric currents. From these experiments, Thomson was able to conclude that negatively charged particles were present in all matter, and in fact might be the stuff of which matter is made. The amber effect was traced to the movement of these particles, so they were called *electrons* after the Greek word for amber. The word *electricity* is also based on the Greek word for amber.

Today, we understand that the basic unit of matter is the *atom*, which is made up of electrons and other particles such as *protons* and *neutrons*. The atom is considered to have a dense center part called a *nucleus* that contains the closely situated protons and neutrons. The electrons move around the nucleus at some relatively greater distance (Figure 6.2). Details on the nature of protons, neutrons, electrons, and models of how the atom is constructed will be considered in chapter 8. For understanding electricity, you need only consider the protons in the nucleus, the electrons that move around the nucleus, and the fact that electrons can be moved from an atom and caused to move to or from one object to another. Basically, the electrical, light, and chemical phenomena involve the *electrons* and not the more massive nucleus. The massive nuclei remain in a relatively fixed position in a solid, but some of the electrons can move about from atom to atom.

Electric Charge and Electrical Forces

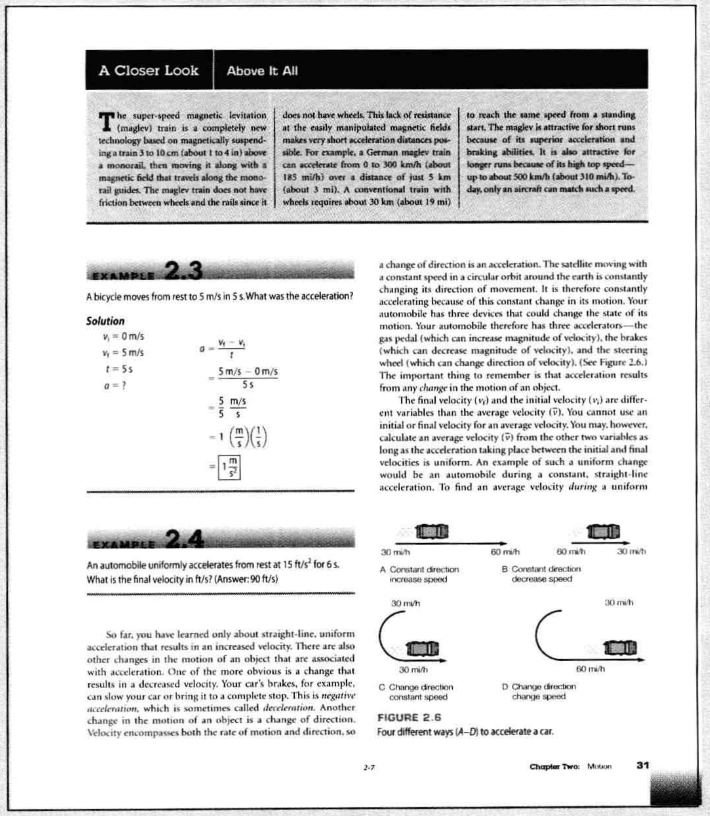
Electrons and protons have a property called electric charge. Electrons have a *negative electric charge* and protons have a *positive electric charge*. The negative or positive description simply means that these two properties are opposite; it does not mean that one is better than the other. Charge is as fundamental to

142 Chapter Six: Electricity 6-2

Examples

Each topic discussed within the chapter contains one or more concrete, worked *Examples* of a problem and its solution as it applies to the topic at hand. Through careful study of these examples, students can better appreciate the many uses of problem solving in the physical sciences.

> *"I feel this book is written well for our average student. The images correlate well with the text, and the math problems make excellent use of the dimensional analysis method. While it was a toss-up between this book and another one, now that we've taught from the book for the last year, we are extremely happy with it."*
> —Alan Earhart, Three Rivers Community College



A Closer Look | Above It All

The super-speed magnetic levitation (maglev) train is a completely new technology based on magnetically suspending a train 3 to 10 cm (about 1 to 4 in) above a monorail, then moving it along with a magnetic field that travels along the monorail guides. The maglev train does not have friction between wheels and the rails since it does not have wheels. This lack of resistance at the easily manipulated magnetic fields makes very short acceleration distances possible. For example, a German maglev train can accelerate from 0 to 300 km/h (about 185 mi/h) over a distance of just 5 km (about 3 mi). A conventional train with wheels requires about 30 km (about 19 mi) to reach the same speed from a standing start. The maglev is attractive for short runs because of its superior acceleration and braking abilities. It is also attractive for longer runs because of its high top speed—up to about 500 km/h (about 310 mi/h). Today, only an aircraft can match such a speed.

EXAMPLE 2.3

A bicycle moves from rest to 5 m/s in 5 s. What was the acceleration?

Solution

$v_i = 0$ m/s
$v_f = 5$ m/s
$t = 5$ s
$a = ?$

$$a = \frac{v_f - v_i}{t} = \frac{5\ \text{m/s} - 0\ \text{m/s}}{5\ \text{s}} = \frac{5}{5}\ \frac{\text{m/s}}{\text{s}} = 1\left(\frac{\text{m}}{\text{s}}\right)\left(\frac{1}{\text{s}}\right) = \boxed{1\ \frac{\text{m}}{\text{s}^2}}$$

EXAMPLE 2.4

An automobile uniformly accelerates from rest at 15 ft/s^2 for 6 s. What is the final velocity in ft/s? (Answer: 90 ft/s)

So far, you have learned only about straight-line, uniform acceleration that results in an increased velocity. There are also other changes in the motion of an object that are associated with acceleration. One of the more obvious is a change that results in a decreased velocity. Your car's brakes, for example, can slow your car or bring it to a complete stop. This is *negative acceleration*, which is sometimes called *deceleration*. Another change in the motion of an object is a change of direction. Velocity encompasses both the rate of motion and direction, so a change of direction is an acceleration. The satellite moving with a constant speed in a circular orbit around the earth is constantly changing its direction of movement. It is therefore constantly accelerating because of this constant change in its motion. Your automobile has three devices that could change the state of its motion. Your automobile therefore has three accelerators—the gas pedal (which can increase magnitude of velocity), the brakes (which can decrease magnitude of velocity), and the steering wheel (which can change direction of velocity). (See Figure 2.6.) The important thing to remember is that acceleration results from any *change* in the motion of an object.

The final velocity (v_f) and the initial velocity (v_i) are different variables than the average velocity ($\bar{v}$). You cannot use an initial or final velocity for an average velocity. You may, however, calculate an average velocity ($\bar{v}$) from the other two variables as long as the acceleration taking place between the initial and final velocities is uniform. An example of such a uniform change would be an automobile during a constant, straight-line acceleration. To find an average velocity *during* a uniform

30 mi/h 60 mi/h
A Constant direction increase speed
60 mi/h 30 mi/h
B Constant direction decrease speed
30 mi/h 30 mi/h
C Change direction constant speed
30 mi/h 60 mi/h
D Change direction change speed

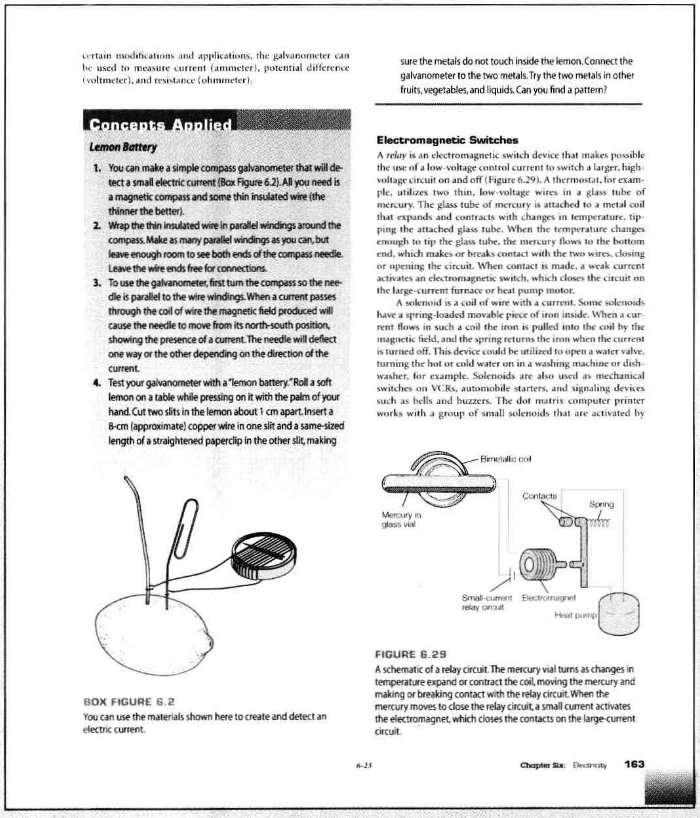
FIGURE 2.6
Four different ways (A–D) to accelerate a car.

2-7 Chapter Two: Motion 31

Applying Science to the Real World

Concepts Applied

Each chapter also includes one or more *Concepts Applied* boxes. These activities are simple investigative exercises that students can perform at home or in the classroom to demonstrate important concepts and reinforce understanding of them. This feature also describes the application of those concepts to everyday life.

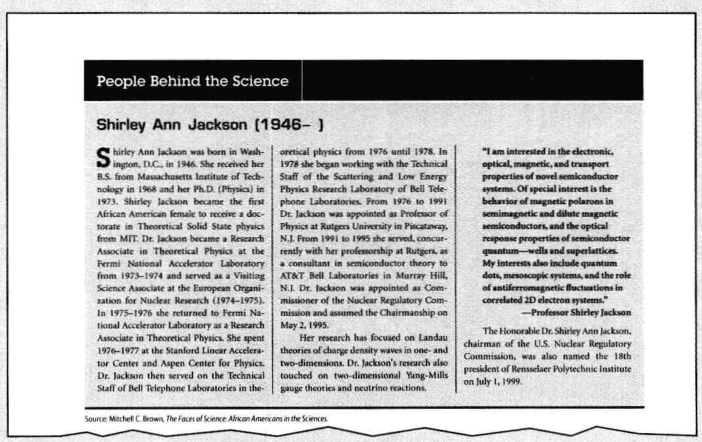


Closer Look

One or more boxed *Closer Look* features can be found in each chapter of *Physical Science.* These readings present topics of special human or environmental concern (the use of seat belts, acid rain, and air pollution, for example). In addition to environmental concerns, topics are presented on interesting technological applications (passive solar homes, solar cells, catalytic converters, etc.), or topics on the cutting edge of scientific research (for example, El Niño and Dark Energy). All boxed features are informative materials that are supplementary in nature. The *Closer Look* readings serve to underscore the relevance of physical science in confronting the many issues we face daily.

People Behind the Science

Many chapters also have one or two fascinating biographies that spotlight well-known scientists, past or present. From these *People Behind the Science* biographies, students learn about the human side of the science: physical science is indeed relevant, and real people do the research and make the discoveries. These readings present physical science in real-life terms that students can identify with and understand.



"The People Behind the Science features help relate the history of science and the contributions of the various individuals."

—Richard M. Woolheater, Southeastern Oklahoma State University

End-of-Chapter Features

At the end of each chapter, students will find the following materials:

- *Summary:* highlights the key elements of the chapter.
- *Summary of Equations* (chapters 1–13): reinforces retention of the equations presented.
- *Key Terms:* gives page references for finding the terms defined within the context of the chapter reading.
- *Applying the Concepts:* tests comprehension of the material covered with a multiple-choice quiz.
- *Questions for Thought:* challenges students to demonstrate their understanding of the topics.
- *Parallel Exercises* (chapters 1–13): reinforces problem-solving skills. There are two groups of parallel exercises, Group A and Group B. The Group A parallel exercises have complete solutions worked out, along with useful comments, in appendix D. The Group B parallel exercises are similar to those in Group A but do not contain answers in the text. By working through the Group A parallel exercises and checking the solutions in appendix D, students will gain confidence in tackling the parallel exercises in Group B, and thus reinforce their problem-solving skills.


Summary

Summary of Equations

7.1

angle of incidence = angle of reflection

$\theta_i = \theta_r$

7.2

$$\text{index of refraction} = \frac{\text{speed of light in vacuum}}{\text{speed of light in material}}$$

$$n = \frac{c}{v}$$

7.3

speed of light in vacuum = (wavelength)(frequency)

$$c = \lambda f$$

7.4

$$\text{energy of photon} = \left(\text{Planck's constant}\right)(\text{frequency})$$

$$E = hf$$

KEY TERMS

blackbody radiation (p. **180**)
incandescent (p. **180**)
index of refraction (p. **187**)
interference (p. **191**)
light ray model (p. **182**)
luminous (p. **180**)
photoelectric effect (p. **195**)
photons (p. **196**)
polarized (p. **194**)
quanta (p. **196**)
real image (p. **201**)
refraction (p. **201**)
total internal reflection (p. **186**)
unpolarized light (p. **194**)
virtual image (p. **185**)

APPLYING THE CONCEPTS

1. A luminous object is an object that
   a. reflects a dim blue-green light in the dark.
   b. produces light of its own by any method.
   c. shines by reflected light only, such as the moon.
   d. an object that glows only in the absence of light.
2. An object is hot enough to emit a dull red glow. When this object is heated even more, it will
   a. emit shorter-wavelength, higher-frequency radiation.
   b. emit longer-wavelength, lower-frequency radiation.
   c. emit the same wavelengths as before, but with more energy.
   d. emit more of the same wavelengths with more energy.
3. The difference in the light emitted from a candle, an incandescent lightbulb, and the sun is basically from differences in
   a. energy sources.
   b. materials.
   c. temperatures.
   d. phases of matter.

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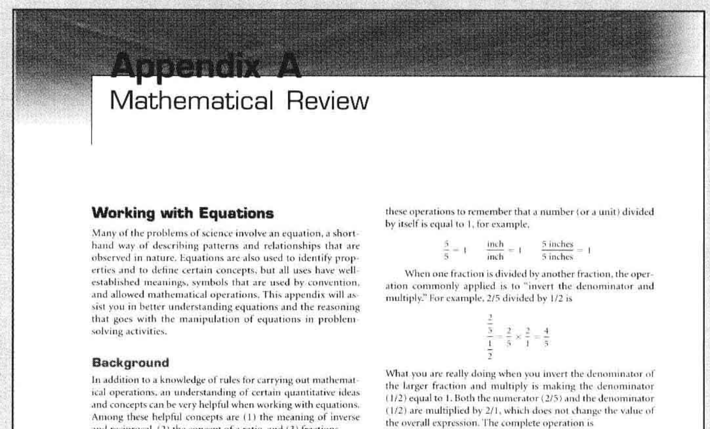
"I like this [Summary of Equations] feature. It collects the equations together for easy reference. . . . I also like this [Key Terms] feature. It is well organized, thorough and gives the student a tool for review. The instructor can also use it for a checklist of topics. . . . The end-of-chapter features of Summary of Equations and Key Terms make the chapters very user-friendly."
—Richard M. Woolheater, Southeastern Oklahoma State University

"The Parallel Exercises and the explanation in the appendix, the readability of the material, and the depth of coverage are the strongest features of this text."
—Martha K. Newchurch, Nicholls State University

"The provision of solutions to a set of problems as a guide for solving identical problems on an adjacent set is an ingenious learning tool."
—Ignatius Okafor, Jarvis Christian College

End-of-Text Materials

Appendices providing math review, additional background detail, solubility and humidity charts, and solutions for the Group A Parallel Exercises can be found at the back of the text. There is also a glossary of all key terms, an index, and special tables printed on the inside covers for reference use.


Appendix A
Mathematical Review

Working with Equations

Background

Symbols and Operations

Operations in Equations

A-1 595

Supplements

Physical Science is accompanied by a variety of multimedia supplementary materials, including an interactive website; an Instructor's Testing and Resource CD-ROM, with testing software containing multiple-choice test items for the text and other teacher resources; and a Digital Content Manager CD-ROM, with digital images from the text. The supplement package also contains more traditional supplements: a laboratory manual and overhead transparencies.

Multimedia Supplementary Materials

Online Learning Center

A text-specific website, our *Physical Science* Online Learning Center, offering unlimited resources for both the student and instructor, can be found at: www.mhhe.com/tillery/. By way of this website, students and instructors will be better able to quickly incorporate the Internet into their classrooms. This interactive resource is packaged free with any new textbook.

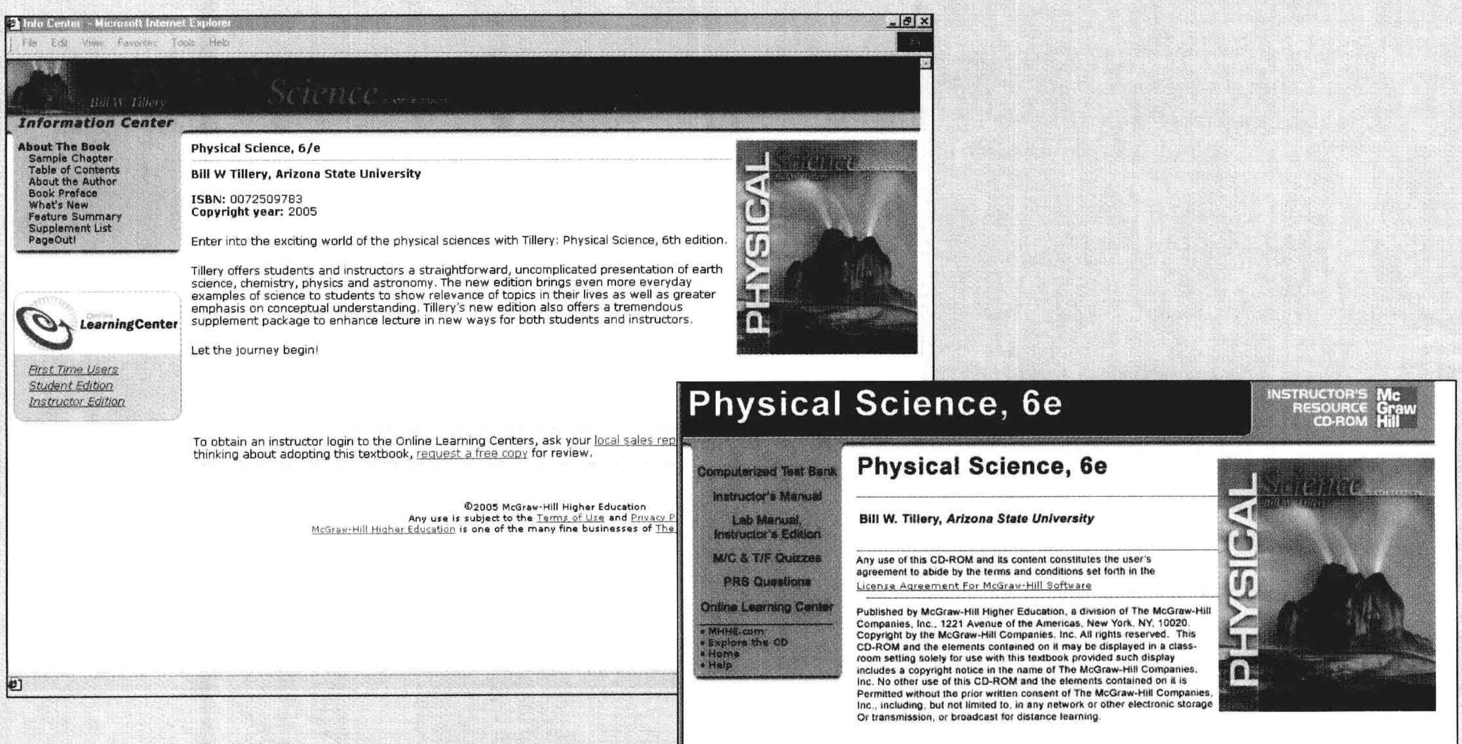
Student Edition of the Online Learning Center. The *Physical Science, Sixth Edition* Online Learning Center has book-specific study aids organized by chapter. Each chapter includes animations modeling key concepts discussed in the book; interactive questions and problems, such as self-test quizzes and crossword puzzles, flashcards, and matching exercises using key terms and glossary definitions; chapter resources; and web-linked resources. Also included are Exploring Physical Science articles, which expose students to a different viewpoint on a topic or a new research project, as well as links to McGraw-Hill's Access Science and PowerWeb sites, which provide additional research resources.

Instructor's Edition of the Online Learning Center. For instructors, there is an image bank containing the images from the text, PowerPoint lectures, a bank of personal response system questions, the *instructor's manual*, the *instructor's edition of the laboratory manual,* clip art, a database of equations, and much more. From the student edition, instructors can access questions and problems from the text and additional Closer Look questions with e-mail boxes for gradable responses from students.

The *instructor's manual,* also written by the text author, is housed on the Online Learning Center and provides a chapter outline, an introduction/summary of each chapter, suggestions for discussion and demonstrations, multiple-choice questions (with answers) that can be used as resources for cooperative teaching, and answers and solutions to all end-of-chapter questions and exercises not provided in the text.

Instructor's Testing and Resource CD-ROM

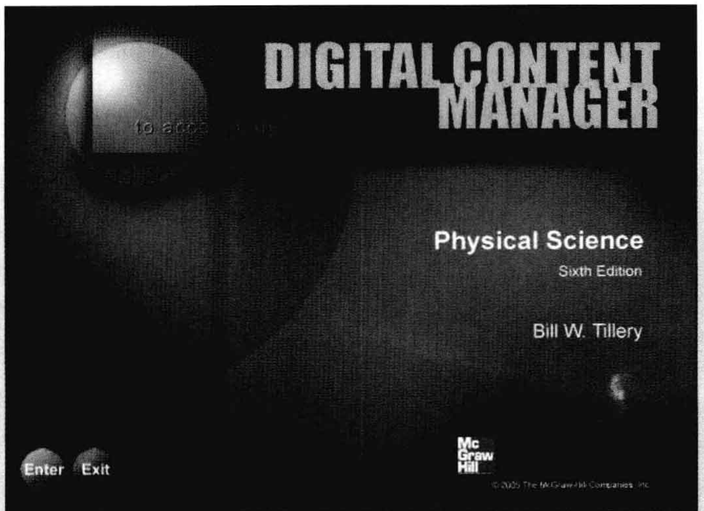
The **Instructor's Testing and Resource CD-ROM** contains the *Physical Science* test bank (test questions in a combination of true/false and multiple-choice formats) within the Brownstone DIPLOMA© test generator. The Brownstone software includes a test generator, an online testing program, Internet testing, and a grade management system. This user-friendly software's testing capability is consistently ranked number one in evaluations over other products. Also located on the Instructor's Testing and Resources CD-ROM are Word and PDF files of the test bank, the instructor's manual, instructor's edition of the laboratory manual, the bank of personal response system questions, and the quizzes from the Online Learning Center. Any of these Word files can be used in combination with the Brownstone software or independently.



Digital Content Manager CD-ROM

The **Digital Content Manager** contains JPEG files of the four-color illustrations, photos, and tables from the text as well as a collection of animations and video clips. The CD also contains a PowerPoint presentation of the text images and another lecture PowerPoint presentation. These digital assets are contained on a cross-platform CD-ROM and are grouped by chapter within a user-friendly interface. With the help of these valuable resources, instructors can create customized classroom presentations, visually based tests and quizzes, dynamic course website content, and attractive printed support materials.

> *"I find Physical Science to be superior to either of the texts that I have used to date. . . . The animations and illustrations are better than those of other textbooks that I have seen, more realistic and less trivial."*
> —T. G. Heil, University of Georgia



Printed Supplementary Material

Laboratory Manual

The *laboratory manual,* written and classroom tested by the author, presents a selection of laboratory exercises specifically written for the interests and abilities of nonscience majors. There are laboratory exercises that require measurement, data analysis, and thinking in a more structured learning environment. Alternative exercises that are open-ended "Invitations to Inquiry" are provided for instructors who would like a less structured approach. When the laboratory manual is used with *Physical Science,* students will have an opportunity to master basic scientific principles and concepts, learn new problem-solving and thinking skills, and understand the nature of scientific inquiry from the perspective of hands-on experiences. The *instructor's edition of the laboratory manual* can be found on the *Physical Science* Online Learning Center.

Overhead Transparencies

A set of over 100 full-color transparencies features images from the text. The images have been modified to ensure maximum readability in both small and large classroom settings.

Acknowledgments

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Bill W. Tillery is a professor in the Department of Physics and Astronomy at Arizona State University, where he has been a member of the faculty since 1973. He earned a bachelor's degree at Northeastern State University (1960), and master's and doctorate degrees from the University of Northern Colorado (1967). Before moving to Arizona State University, he served as director of the Science and Mathematics Teaching Center at the University of Wyoming (1969–73) and as an assistant professor at Florida State University (1967–69). Bill has served on numerous councils, boards, and committees and was honored as the "Outstanding University Educator" at the University of Wyoming in 1972. He was elected the "Outstanding Teacher" in the Department of Physics and Astronomy at Arizona State University in 1995.

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Bill has attempted to present an interesting, helpful program that will be useful to both students and instructors. Comments and suggestions about how to do a better job of reaching this goal are welcome. Any comments about the text or other parts of the program should be addressed to:

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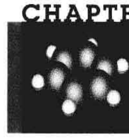

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