Further Reading

C. Canine, *Dream Reaper: The Story of an Old-Fashioned Inventor in the High-Tech, High-Stakes World of Modern Agriculture* (Chicago: University of Chicago Press, 1997).

R. Kanigel, *The One Best Way: Frederick Winslow Taylor and the Enigma of Efficiency* (New York: Viking Press, 1997).

Technology Insert: Agricultural Steam Technology

Sloan Technology Series Source

C. Canine, *Dream Reaper: The Story of an Old-Fashioned Inventor in the High-Tech, High-Stakes World of Modern Agriculture* (Chicago: University of Chicago Press, 1997).

Other Sources:

D. Fitzgerald, Beyond tractors: The history of technology in American agriculture, *Technology and Culture*, **32,** (1991), pp. 114–26.

R. Leffingwell, *The American Farm Tractor: A History of the Classic Tractor* (Osceola, WI: Motorbooks International, 1991).

J.T. Schelbecker, *Whereby We Thrive: A History of American Farming, 1607–1972* (Ames, IA: ISU Press, 1975).

R.C. Williams, *Fordson, Farmall, and Poppin' Johnny: A History of the Farm Tractor and Its Impact on America* (Chicago: University of Illinois Press, 1987).

CHAPTER 7. HEAT—A MATTER OF MOTION

Suggested Mini-Laboratory Explorations

- Three States of Matter.
- How Do We Know That Atoms Really Exist? The Brownianscope.

Suggested Major Laboratory Explorations

- Exploring Heat Transfer and the Latent Heat of Fusion.

Demonstrations

One demonstration of the concept of entropy as disorder involves the use of marbles of two different colors in a box. One color might represent an ice cube or a small amount of a gas, placed together in one corner of the

box. The other marbles will represent air molecules. "Warm" the arrangement by gently shaking. Discuss what happens, and the probability that further shaking may bring the marbles back into their original arrangement.

Computer simulations and video examples of Brownian motion can be used in conjunction with the Brownianscope.

Demonstrations of some aspects of the ideal gas law using a balloon.

Objectives

These two chapters (6 and 7) introduce students to the study of heat and the laws of thermodynamics, and to the kinetic–molecular theory of matter as one way of understanding the behavior of gases and thermodynamic properties. Chapter 6 aims to show the nature and importance of thermodynamics and its connection with the rise of steam-engine technology. Chapter 7 also aims to show the importance and nature of the atomic hypothesis and the kinetic theory as one basis for providing a sub-microscopic, mechanical account of such macroscopic phenomena as the laws of thermodynamics and the ideal gas law.

Suggestions

Together, these two chapters (6 and 7) cover a great deal of physics content as well as providing important examples of the processes of theory construction, modeling, and the significance of the atomic hypothesis. Both chapters also emphasize the connection of these developments with the emerging steam technology and the Industrial Revolution. These themes will continue through the coming chapters.

Many of the concepts here, such as temperature, atoms, entropy, pressure, and so on, are fundamental to all of physics. (However, the Periodic Table is not introduced formally until Chapter 13, *Probing the Atom*.) Leave as much time as possible for students to assimilate the material. They may have encountered some of these concepts in the past but their understanding of them is often only partial. Students should also have as much opportunity as possible to encounter the phenomena and concepts in the laboratory in parallel with their reading of the text.

Further Reading

G. Holton and S.G. Brush, *Physics, The Human Adventure* (Piscataway, NJ: Rutgers University Press, 2001), Chapters 18, 19, 22.

C.E. Swartz and T. Miner, *Teaching Introductory Physics: A Sourcebook* (Woodbury, NY: AIP Press, 1997), Chapters 10, 11.

H.C. Von Baeyer, *Maxwell's Demon: Why Warmth Disperses and Time Passes* (New York: Random House, 1998). Paperback: *Warmth Disperses and Time Passes: The History of Heat* (New York: Modern Library, 1999).

Students might also be encouraged to undertake some outside readings that express the joy and wonder of discovery, such as the biographical or autobiographical works of Benjamin Franklin, Richard P. Feynman, and others.

CHAPTER 8. WAVE MOTION

Suggested Mini-Laboratory Explorations

- Light and Color.

Suggested Major Laboratory Explorations

- Investigating Waves.

Project Physics Classic Videos

Superposition
Standing Waves in a String
Standing Waves in a Gas
Four Loops on Vibrations
People and Particles

Available in VHS and DVD formats with new audio tracks and sound effects, *Physics: Cinema Classics* (Lexington, KY: Ztek Co.): http://www.ztek.com.

Demonstrations

Many of the wave and optical effects discussed in this chapter can and should be demonstrated in class, with student participation, as well as explored in the laboratory.

Polarization can be strikingly demonstrated by using two pairs of Polaroid sun glasses or the three-dimensional eyeglasses currently used in three-dimensional Imax presentations. The three-dimensional effect is generated by two projectors alternately projecting images on the screen that

are polarized perpendicular to each other. Each lens in the glasses allows only one of the two polarized images to pass. By rotating the lenses of two pairs of glasses, the polarizing affect is evident.

Objectives

Waves should be studied in the laboratory. Most of this chapter is only a summary of some of what students might learn there. Understanding and recognizing wave phenomena are essential for understanding many important contemporary applications and for understanding the foundations of quantum mechanics. Students should be able to distinguish waves and particles from the differences in their behavior in various situations. This chapter also provides another example of theory construction, and the technological implications of recent advances in the area of electromagnetic waves.

Suggestions

This chapter again encompasses many important new concepts, and it provides many opportunities for hands-on experience with wave and optical phenomena. Such hands-on experience should closely parallel the first half of the chapter.

In an effort to reduce the number of topics to an essential minimum, we have not included the properties of lenses or the equations pertaining to refraction and interference. Some excellent laboratory inquiries on optical reflection and refraction are provided by L.C. McDermott et al., *Physics by Inquiry* (New York: Wiley, 1996), Vol. 2.

Further Reading

G. Holton and S.G. Brush, *Physics, The Human Adventure* (Piscataway, NJ: Rutgers University Press, 2001), Chapter 23.

A.B. Arons, *A Guide to Introductory Physics Teaching* (New York: Wiley, 1990), Chapter 9.

C.E. Swartz and T. Miner, *Teaching Introductory Physics: A Sourcebook* (Woodbury, NY: AIP Press, 1997), Chapters 13–15.

D. Park, *The Fire within the Eye: A Historical Essay on the Nature and Meaning of Light* (Princeton, NJ: Princeton University Press, 1997).

R. Buderi, *The Invention That Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution* (New York: Touchstone Books, 1998).

J. Hecht, *City of Light: The Story of Fiber Optics*, (New York: Sloan Technology Series, Oxford University Press, 1999).

Technology Insert: Radar Technology

Further Reading

Sloan Technology Series Source:

R. Buderi, *The Invention That Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution* (New York: Touchstone Books, 1998).

Other Sources:

R. Baldwin, *The Deadly Fuze: Secret Weapon of World War II* (San Rafael, CA: Presidio Press, 1980).

M. Bertolotti, *Masers and Lasers: An Historical Approach* (Bristol, UK: Hilger, 1983).

B. Bruce-Briggs, *The Shield of Faith: A Chronicle of Strategic Defense from Zepplins to Star Wars* (New York: Simon and Schuster, 1988).

R. Burns, ed., *Radar Development to 1945* (London: Peter Peregrinus, 1988).

E.B. Callick, *Metres to Microwaves* (London: Peter Peregrinus, 1990).

R. Clark, *Tizard* (London: Methuen, 1965).

M.R. Gordon and B.E. Trainor, *The General's War* (Boston, MA: Little Brown, 1995).

H.E. Guerlac, *Radar in World War II* (New York: Tomash, American Institute for Physics, 1987).

F.H. Hinsley and A. Stripp, eds., *Codebreakers: The Inside Story of Bletchley Park* (Oxford, UK: Oxford University Press, 1994).

R.V. Jones, *The Wizard War: British Scientific Intelligence 1939–1945* (New York: Coward, McCann & Geoghegan, 1978).

D.J. Kevles, Scientists, the military, and the control of postwar defense research: The case of the Research Board for National Security, 1944–46, *Technology and Culture* **16**, (1975), 20–47.

S.W. Leslie, *The Cold War and American Science: The Military–Industrial–Academic–Complex at MIT and Stanford* (New York: Columbia University Press, 1993).

J. Nissen and A.W. Cockerill, *Winning the Radar War* (New York: St. Martin's/Marek, 1987).

J.S. Rigden, *Rabi: Scientist and Citizen* (New York: Basic Books, 1987).

C.P. Snow, *Science and Government* (Cambridge, MA: Harvard University Press, 1962).

J.C. Toomay, *Radar Principles for the Non-Specialist*, 2nd ed. (New York: Van Nostrand Reinhold, 1989).

CHAPTER 9. EINSTEIN AND RELATIVITY THEORY

Suggested Mini-Laboratory Explorations

- Relative Motion (Section 9.3), if not already performed.

Computer Laboratory Exploration

"Spacetime: A Computer Excursion into Relativity Theory" is based upon the award-winning software program *Spacetime* by E.F. Taylor, American Institute of Physics, Physics Academic Software, 1991.

Videos

Einstein: The Private Thoughts of a Public Genius, Nova Production, WGBH Boston, Vestron Video, 1979.

A. Einstein: How I See the World, PBS Home Video, n.d.

Space, Time, and Albert Einstein (Wilmette, IL: Films Inc., 1979). An excellent survey of the man, his influence, and his relativity theories.

Objectives

In this chapter students should appreciate first hand the capabilities and beauty of an essential part of contemporary physics. Moreover, they will gain a sense of personal achievement, if they have not done so already, in comprehending a subject that most will believe at first to be far beyond their capabilities. Students will also learn about a type of theory that has similarities with Copernicus's approach, and they will further appreciate how mathematical expressions can have profound physical meaning.

Suggestions

One of the most difficult concepts is that of relative motion, even though the ground has already been prepared in previous chapters and in laboratory work. Students should carefully study or restudy the mini-laboratory exploration on relative motion.

Further Reading

There is a great deal of literature available for instructors and students on Einstein and the theory of special relativity. Excellent advice on presenting this material is offered by A.B. Arons, *A Guide to Introductory Physics Teaching*, Section 10.12, and C.E. Swartz and T. Miner, *Teaching Introductory Physics: A Sourcebook*, Chapter 6, "Reference Frames and Relativity." See also:

D. Cassidy, *Einstein and Our World* (Amherst, NY: Prometheus Books, 1995).

A. Einstein, *Ideas and Opinions* (New York: Bonanza Books, 1988).

A. Einstein, *Relativity: The Special and the General Theory* (New York: Crown, 1995), and many other editions; originally published 1917.
A. Einstein, *The World As I See It* (New York: Citadel Press, 1993).
A. Einstein and L. Infeld, *The Evolution of Physics* (New York: Simon and Schuster, 1967).
A. Fölsing, *Albert Einstein: A Biography*, E. Osers, transl. (New York: Penguin, 1998).
P. Frank and G. Rosen, *Einstein: His Life and Times*, rev. ed. (New York: Da Capo, 1989).
M. Gardner, *Relativity Simply Explained* (New York: Dover, 1997).
B. Hoffmann, *Albert Einstein: Creator and Rebel* (New York: Viking Press, 1972).
G. Holton, *Einstein, History and Other Passions* (Cambridge, MA: Harvard University Press, 2000).
G. Holton, *Thematic Origins of Scientific Thought: Kepler to Einstein* (Cambridge, MA: Harvard University Press, 1988), Part II: "On Relativity Theory."
G. Holton and S.G. Brush, *Physics, The Human Adventure* (Piscataway, NJ: Rutgers University Press, 2001), Chapter 30.
J. Stachel, ed. and transl., *Einstein's Miraculous Year: Five Papers That Changed the Face of Physics* (Princeton, NJ: Princeton University Press, 1998). Contains translations of the original papers of 1905, including the first two on special relativity. These are beyond the scope of this course, but students may be intrigued to see the original papers and to note the seemingly simple early passages. Some students may be encouraged to read further.
E.F. Taylor, and J.A. Wheeler, *Spacetime Physics: Introduction to Special Relativity*, 2nd ed. (New York: Freeman, 1992). H.Woolf, ed., *Some Strangeness in the Proportion: A Centennial Symposium to Celebrate the Achievements of Albert Einstein* (Reading, MA: Addison-Wesley, 1980).

Web sites

A. Einstein: Image and Impact: http://www.aip.org/history/einstein
A. Einstein: http://www.pbs.org/wgbh/nova/einstein