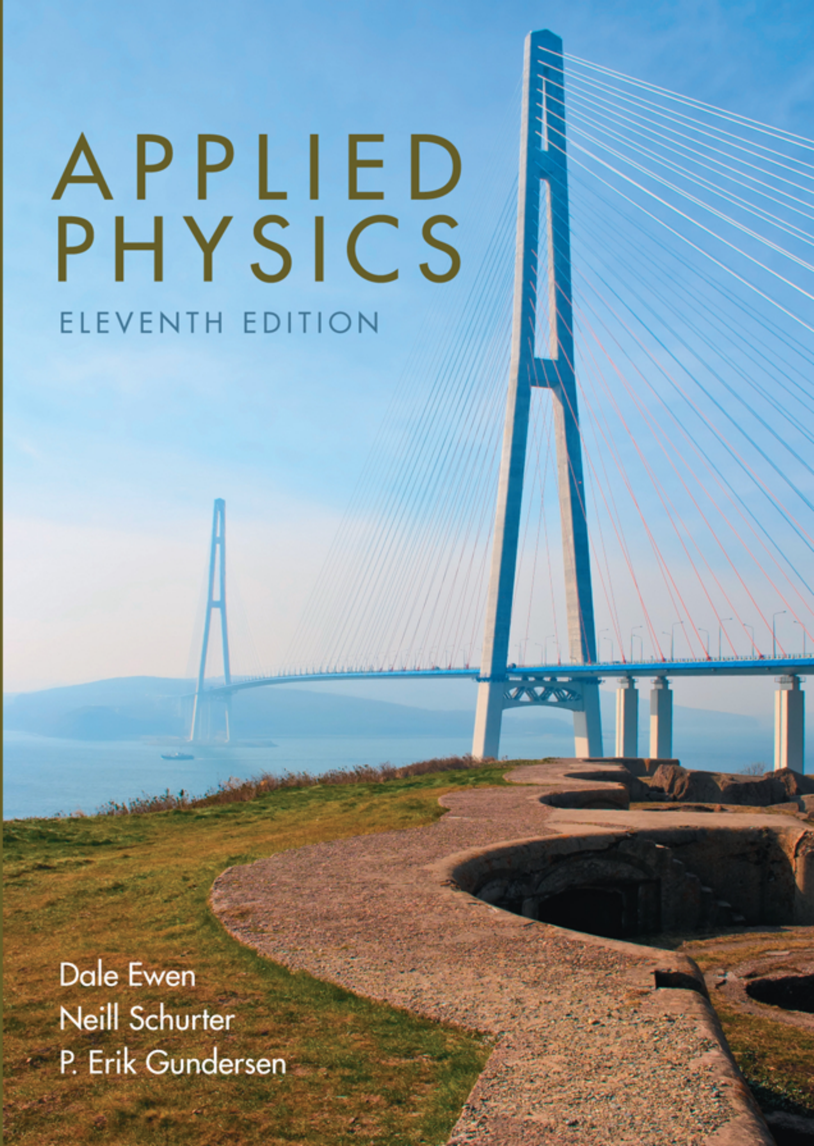

APPLIED PHYSICS

ELEVENTH EDITION

Dale Ewen
Neill Schurter
P. Erik Gundersen

FORMULAS FROM PHYSICS

Velocity and Acceleration

$s = vt$

$\Delta v = at$

$v_{avg} = \frac{v_f + v_i}{2}$

$a = \frac{v_f - v_i}{t}$

$s = v_i t + \frac{1}{2}at^2$

$v_f = v_i + at$

$s = \frac{1}{2}(v_f + v_i)t$

$2as = v_f^2 - v_i^2$

Force

$F = ma$

$F_f = \mu F_N$

$F_w = mg$

$p = mv$

impulse $= Ft = \Delta p = mv_f - mv_i$

$\tau = Fs_r$

Noncurrent Forces

The sum of all parallel forces must be zero. The sum of the clockwise torques must equal the sum of the counterclockwise torques.

Work and Energy

$W = Fs$

$W = Fs \cos\theta$

$P = \frac{W}{t}$

$E_p = mgh$

$E_k = \frac{1}{2}mv^2$

$v = \sqrt{2gh}$

Rotational Motion

$\theta = \frac{s}{r}$

$\omega = \frac{\theta}{t}$

$v = \omega r$

$\alpha = \frac{\Delta\omega}{t}$

$\tau = I\alpha$

$L = I\omega$

$F = \frac{mv^2}{r}$

$P = \tau\omega$

$NT_1T_2T_3T_4 \cdots = nt_1t_2t_3t_4 \cdots$

$ND_1D_2D_3D_4 \cdots = nd_1d_2d_3d_4 \cdots$

Simple Machines

Law of Simple Machines:

resistance force × resistance distance = effort force × effort distance

$F_R \cdot s_R = F_E \cdot s_E$

$\text{MA} = \frac{\text{resistance force}}{\text{effort force}}$

$\text{MA}_{\text{lever}} = \frac{\text{effort arm}}{\text{resistance arm}}$

$\text{MA}_{\text{wheel and axle}} = \frac{\text{radius of effort}}{\text{radius of resistance}}$

$\text{MA}_{\text{pulley}}$ = number of strands holding the resistance

$\text{MA}_{\text{inclined plane}} = \frac{\text{length of plane}}{\text{height of plane}}$

$\text{MA}_{\text{screw}} = \frac{2\pi r}{\text{pitch}}$

Universal Gravitation

$F_G = G\frac{m_1m_2}{r^2}$

$v = \sqrt{\frac{Gm}{r}}$

$T = 2\pi\sqrt{\frac{r^3}{Gm}}$

Matter

$S = \frac{F}{A}$

$\frac{F}{\Delta l} = k$

$D_m = \frac{m}{V}$

$D_w = \frac{F_w}{V}$

specific gravity $= \frac{D_{\text{material}}}{D_{\text{water}}}$

Fluids

$P = \frac{F}{A}$

$P = hD_w$

$F_t = AhD_w$

$F_s = \frac{1}{2}AhD_w$

$P_{abs} = P_{ga} + P_{atm}$

$Q = vA$

Temperature and Heat

$T_F = \frac{9}{5}T_C + 32°$

$T_C = \frac{5}{9}(T_F - 32°)$

$T_R = T_F + 46\overline{0}°$

$T_K = T_C + 273$

$Q = cm\Delta T$

$Q = cw\Delta T$

$\Delta l = \alpha l\Delta T$

$\Delta A = 2\alpha A\Delta T$

$\Delta V = 3\alpha V\Delta T$

$\Delta V = \beta V\Delta T$

$L_f = \frac{Q}{m} \quad L_f = \frac{Q}{w}$

$L_v = \frac{Q}{m} \quad L_v = \frac{Q}{w}$

$\frac{V}{T} = \frac{V'}{T'}$

$\frac{V}{V'} = \frac{P'}{P}$

$\frac{D}{D'} = \frac{P}{P'}$

$\frac{VP}{T} = \frac{V'P'}{T'}$

Wave Motion and Sound

$T = 2\pi\sqrt{\frac{l}{g}}$

$f = \frac{1}{T}$

$v = \lambda f$

$v = 331\text{ m/s} + (0.61\text{ m/s°C})T$

$f' = f\left(\frac{v}{v \pm v_s}\right)$

Electricity

$$F = \frac{kq_1q_2}{r^2}$$

$$R = \frac{\rho L}{A}$$

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

Series Circuits

(a) $I = I_1 = I_2 = I_3 = \cdots$

(b) $R = R_1 + R_2 + R_3 + \cdots$

(c) $E = V_1 + V_2 + V_3 + \cdots$

Parallel Circuits

(a) $I = I_1 + I_2 + I_3 + \cdots$

(b) $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$

(c) $E = V_1 = V_2 = V_3 = \cdots$

Cells in Series

(a) $I = I_1 = I_2 = I_3 = \cdots$

(b) $r = r_1 + r_2 + r_3 + \cdots$

(c) $E = E_1 + E_2 + E_3 + \cdots$

Cells in Parallel

(a) $I = I_1 + I_2 + I_3 + \cdots$

(b) $r = \frac{r \text{ of one cell}}{\text{number of like cells}}$

(c) $E = E_1 = E_2 = E_3 = \cdots$

$V = E - Ir$

$P = VI = I^2R = \frac{V^2}{R}$

Magnetism

$$B = \frac{\mu_0 I}{2\pi R}$$

$$B = \pi_0 I n$$

Transformers

$$\frac{V_P}{V_S} = \frac{N_P}{N_S}$$

$$\frac{I_S}{I_P} = \frac{N_P}{N_S}$$

ac Circuits

$$X_L = 2\pi f L$$

$$I = \frac{E}{X_L}$$

$$I = \frac{E}{Z}$$

$$Z = \sqrt{R^2 + X_L^2}$$

$$\tan\phi = \frac{X_L}{R}$$

$$X_C = \frac{1}{2\pi f C}$$

$$Z = \sqrt{R^2 + X_C^2}$$

$$\tan\phi = \frac{X_C}{R}$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$\tan\phi = \frac{X_L - X_C}{R}$$

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Light

$$c = \lambda f$$

$$E = hf$$

$$E = \frac{I}{4\pi r^2}$$

$$\frac{1}{f} = \frac{1}{s_o} + \frac{1}{s_i}$$

$$M = \frac{h_i}{h_o} = \frac{-s_i}{s_o}$$

$$n = \frac{\sin i}{\sin r} = \frac{\text{speed of light in vacuum}}{\text{speed of light in substance}}$$

$$\sin i_c = \frac{1}{n}$$

Modern Physics

$$E = -\frac{kZ^2}{n^2}$$

$$E = \Delta mc^2$$

$$Q = (M_p - M_d - m_\alpha)c^2$$

$$N = N_0 e^{-\lambda t}$$

$$T_{1/2} = \frac{0.693}{\lambda}$$

$$A = \lambda N = \lambda N_0 e^{-\lambda t} = A_0 e^{-\lambda t}$$

APPLIED PHYSICS

ELEVENTH EDITION

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CONTENTS

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New to This Edition

- All art has been reviewed, evaluated, and redrawn in four-color as appropriate.
- The new feature "Physics on the Job" highlights real jobs where people use physics in their career. Understanding the connection between physics and various careers provides additional relevance for the physics content highlighted in the respective chapter.
- The new feature "New Technologies" provides up-to-date examples of how physics concepts in the chapter are being utilized in cutting-edge research and products.
- A major effort was made on color photo selection to enhance student learning.
- Some examples and problems were added or changed based on recommendations by reviewers.
- Section A.6 Law of Sines and Cosines has been moved back into the text from online for those students who have completed a trigonometry course and need a review.

Applied Physics, 11th edition, provides comprehensive and practical coverage of physics for students needing an applied physics approach or considering a vocational–technical career. It emphasizes physical concepts as applied to industrial–technical fields and uses common applications to improve the physics and mathematics competence of the student. This edition has been carefully reviewed, and special efforts have been taken to emphasize the clarity and accuracy of presentation.

This text is divided into five major areas: mechanics, matter and heat, wave motion and sound, electricity and magnetism, and light and modern physics.

Key Features

- Real-world applications are used to motivate students.
- Topic coverage is clear and to the point.
- A unique problem-solving format is consistently used throughout the text. This textbook teaches students to use a proven effective problem-solving methodology. The consistent use of this method trains students to make a sketch, identify the data elements, select the appropriate equation, solve for the unknown quantity, and substitute the data in the working equation. An icon that outlines the method is placed in the margin of most problem sets as a reminder to students. See Section 2.3 for the detailed presentation of the problem-solving method.
- Detailed, well-illustrated examples in the problem-solving format support student understanding of skills and concepts. Worked examples are consistently displayed in the problem-solving format and used to illustrate and clarify basic concepts and problems. Since many students learn by example, a large number of examples are provided.
- Problems and questions assist student learning, with extensive problem sets at the end of most sections that provide students with ample opportunity for practice.
- A four-color format with numerous drawings, diagrams, and photographs is used to illustrate the application of physics in the real world and improve student interest and comprehension.
- Try This Activity features provide students with opportunities to experiment with physics concepts. Activities involve a demonstration or mini-activity that can be performed by students on their own to experience a physics concept, allowing for more active versus passive learning.

Examples of Key Features

Chapter Openers

The chapter openers contain the learning objectives that list the major goals of the chapter.

CHAPTER 5

FORCE

Objectives

The major goals of this chapter are to enable you to:

1. Relate force and the law of inertia.
2. Apply the law of acceleration.
3. Identify components of friction.
4. Analyze forces in one dimension.
5. Distinguish among weight, mass, and gravity.
6. Analyze how the law of action and reaction is used.

Classical physics is sometimes called Newtonian physics in honor of Sir Isaac Newton, who lived from 1642 to 1727 and formulated three laws of motion that summarize much of the behavior of moving bodies. Forces may cause motion. Inertia tends to resist the influence of an applied force. Forces, inertia, friction, and how they relate to motion are considered now.

5.1 Force and the Law of Inertia

As discussed in the previous chapter, if an object changes its velocity, we say it accelerates. But what causes an object to accelerate? Let's take an example of a soccer ball at rest on a field. What must you do to accelerate the ball? Similarly, if your car is approaching a red stoplight, what must you do to make the car accelerate to rest? The answer in both instances is to apply a force.

A **force** is any push or pull. Forces tend to either change the motion of an object or prevent the object from changing its motion. Force is a vector quantity and therefore has both magnitude and direction. The force tends to produce acceleration in the direction of its application. Therefore, if you want to accelerate the soccer ball,

Physics Connections

These features apply physics to familiar real-world situations and events. These brief readings help students bridge the gap between what is taught in the chapter and real-world technical applications.

PHYSICS CONNECTIONS

Global Positioning Satellites

Navigators continually struggle to find better tools to help them determine their location. The first explorers used the sun and stars to help them steer a straight course, but this method of navigation only worked under clear skies. Magnetic compasses were developed yet could only be used to determine longitude, not latitude. Finally, the mechanical clock, in conjunction with the compass, provided navigators with the most accurate method of determining location. Today, most navigators use a handheld device that functions in concert with a series of 24 orbiting satellites. This network, the Global Positioning System (GPS), can determine your position and altitude anywhere on earth.

The GPS pinpoints your location by sending out radio signals to locate any 4 of the 24 orbiting GPS satellites. Once the satellites are found, the GPS measures the length of time it takes for a radio signal to reach the handheld receiver. When the time is determined for each of four satellites, the distance is calculated, and the longitude, latitude, and altitude are displayed on the screen [Fig. 3.39(a)].

The GPS was first developed solely for military use. Eventually, the GPS was made available for civilian businesses. Shipping, airline, farming, surveying, and geological companies made use of the technology. Today, GPS receivers are affordable and are used by the general public [Fig. 3.39(b)]. More sophisticated receivers not only locate a position, but can also guide the navigator to a predetermined location. Several automobile manufacturers have included GPS receivers as an option in their cars. Such receivers come complete with voice commands, such as "Turn left at the next traffic light," as part of their option packages.

Try This Activity

These activities provide students with opportunities to experiment with physics concepts. Activities involve a demonstration or mini-activity that can be performed by students on their own to experience a physics concept, allowing for active versus passive learning.

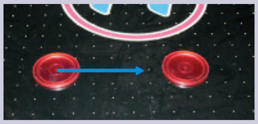
TRY THIS ACTIVITY

Air Hockey Physics

Physics laboratory experiments often use air tracks or low-friction carts to study the conservation of momentum throughout collisions. Air hockey tables are typically more accessible for students and provide the low-friction surface that is needed to study the conservation of momentum. If you have access to an air hockey table, try the following collisions:

For elastic collisions, make sure that the pucks strike one another "head on" by aiming one puck directly toward the center of a stationary puck (Fig. 6.6). Make observations about the velocity of both pucks before and after the collision.

Figure 6.6 For collisions in one dimension, aim the puck directly at the center of the stationary puck, as indicated by the blue velocity vector in the photo.



To observe an elastic collision for objects with different masses, place two pucks on top of one another with some double-sided tape between them so they remain secure to one another. Repeat the previous experiment by aiming a single puck at the doubled pucks and note the changes in velocity for both sets of pucks before and after the collision.

For inelastic collisions, wrap some double-sided tape around the sides of each of two pucks so they can stick together when they collide. Again, note the velocity of both pucks before and after the collision.

New Technologies

Provides up-to-date examples of how physics concepts in the chapter are being utilized in cutting-edge research and products.

NEW TECHNOLOGIES

Tesla High-Performance Electric Automobile

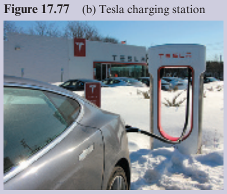
Tesla is a unique automobile as it is considered to be the first-of-its-kind, fully electric and high-performance electric vehicle. Prior to the Tesla, electric cars were hybrid vehicles that relied on a combination of electric power supplemented by gasoline. Until now, pure electric cars were not considered high-performance model vehicles.

The brakes in a Tesla not only slow down the vehicle, but also utilize the energy transfer between brakes and brake pads to create additional energy for the vehicle. This regenerative braking system shifts the kinetic energy typically lost in braking and instead transfers it back to electrical energy for the automobile.

The Tesla Model S has designed a massive 1,000-lb bank of high-density, rechargeable lithium-ion batteries, similar to those used in laptops or other mobile devices. Tesla suggests charging the vehicle overnight in a home garage by plugging the vehicle into a standard 110 V or 220 V circuit. Charging speeds vary between 29 mi of driving range per charging hour at 110 V to 58 mi of driving range per charging hour using a 220 V circuit. Most impressively, Tesla supercharge stations, located at Tesla dealerships and other locations around the nation, can charge up to 340 mi of range per charging hour and can replenish half the battery in 30 minutes (Fig. 17.77)!

Figure 17.77 (a) Tesla Model S electrical vehicle

Figure 17.77 (b) Tesla charging station



PHYSICS ON THE JOB

Power Distribution System Operators

The web of the nation's electrical grid is a massive, complicated, and vital component of the U.S. economy. Too much current traveling through high-voltage wires can overload systems and cause massive blackouts without skilled operators navigating, regulating, and monitoring the flow of electricity as it travels between stations and substations. National power distribution system operators are responsible for monitoring and switching electrical currents to and from regions involved in blackouts or natural disasters. Regional power distribution system operators must be able to adjust electrical currents away from local transformer failures to prevent electrical reflection in transmission lines that can lead to multiple power failures and larger power outages.

Power distribution system operators typically have a minimum of an associate's degree, yet on-the-job training is the most important part of the technical training. Regular professional development is necessary to keep current with modern equipment, especially in the nuclear power industry. In addition, mathematics and physics skills, particularly in the area of electricity and magnetism, are vital to the position (Fig. 19.14).

Figure 19.14 Power distribution system operator

Courtesy of fotolia © dgdimension

Physics on the Job

Highlights real jobs where people use physics in their career.

Unique Problem-Solving Method

This textbook teaches students to use a proven effective problem-solving methodology. The consistent use of this method trains students to make a sketch, identify the data elements, select the appropriate equation, solve for the unknown quantity, and substitute the data in the working equation. An icon that outlines the method is placed in the margin of most problem sets as a reminder to students. See Section 2.3 for the detailed presentation of the problem-solving method.

574 CHAPTER 20 LIGHT

Formulas

20.2 $s = ct$

20.3 $c = \lambda f$

20.4 $E = hf$

20.5 $E = \dfrac{I}{4\pi r^2}$

Review Questions

1. Which of the following are examples of electromagnetic radiation?
   (a) Gamma rays (b) Sound waves (c) Radio waves
   (d) Water waves (e) Visible light
2. The particle theory of light explains
   (a) diffraction of light around a sharp edge.
   (b) refraction of light at a boundary.
   (c) the photoelectric effect.
   (d) none of the above.
3. A light-year equals
   (a) the time it takes light to travel from the sun to the earth.
   (b) the distance from the sun to the earth.
   (c) the distance to the nearest star other than the sun.
   (d) the distance light travels in one earth year.
4. Light behaves
   (a) as a massive particle.
   (b) always as a wave.
   (c) sometimes as a wave, sometimes as a particle.
   (d) as none of the above.
5. Does the wavelength of light depend on its frequency? Explain.
6. How does the energy of a photon of light depend on its frequency?
7. How does the intensity of illumination depend on the distance from a source radiating uniformly in all directions?
8. In your own words, explain how the speed of light has been measured.
9. Does light always travel at the same speed? Explain.
10. What name is given to the entire range of waves that are similar to visible light?
11. Who proposed the particle theory of light?
12. Who developed the wave packet theory of light?
13. Who made the first estimate of the speed of light?
14. How was the first estimate of the speed of light made?
15. What are the units of luminous intensity?
16. In your own words, explain luminous intensity.

Review Problems

1. Find the distance (in metres) traveled by a radio wave in 21.5 h.
2. A radar wave that is bounced off an airplane returns to the radar receiver in 3.78×10^{-5} s. How far (in miles) is the airplane from the radar receiver?
3. How long does it take for a police radar beam to travel to a car and back if the car is 0.245 mi from the radar unit?

CHAPTER 20 LIGHT 575

4. How long does it take for a pulse of laser light to return to a police speed detector after bouncing off a speeding car 0.274 mi away?
5. How long does it take for a radio signal to travel from the earth to a communications satellite 22,500 mi above the surface of the earth?
6. Find the wavelength of a radio wave from an AM station broadcasting at a frequency of 1230 kHz.
7. Find the frequency of a radio wave if its wavelength is 46.5 m.
8. Find the frequency of a light wave if its wavelength is 5.415×10^{-8} m.
9. What is the energy of a photon with frequency 1.45×10^{11} Hz?
10. What is the frequency of a photon with energy of 4.75×10^{-23} J?
11. What is the energy of a photon with frequency 8.25×10^{-15} Hz?
12. Find the intensity of the light source necessary to produce an illumination of 3.75 ft-candles at 6.75 ft from the source.
13. Find the intensity of the light source necessary to produce an illumination of 4.86 lux at 9.25 m from the source.
14. What is the intensity of the light source required to produce the illumination of Problem 13 if the distance from the light source is doubled?
15. What are the maximum and minimum transit times for light traveling from Jupiter to Mars? The orbital radii are 215 million kilometres for Mars and 725 million kilometres for Jupiter. Assume the planetary orbits are circular. Also make the (nonphysical) assumption that the sun is transparent to the transmission of light between the planets.
16. Find the intensity of two identical light sources located 0.454 m and 0.538 m, respectively, from a point where the illumination is 8.46 ℓm/m^2.
17. Find the illumination on a surface by three light sources, each with intensity 125 ℓm, located at 1.85 m, 1.92 m, and 2.43 m from the surface, respectively.

PROBLEM SOLVING

SKETCH

12 cm^2 w

4.0 cm

DATA

$A = 12\text{ cm}^2, l = 4.0\text{ cm}, w = ?$

BASIC EQUATION

$A = lw$

WORKING EQUATION

$w = \dfrac{A}{l}$

SUBSTITUTION

$w = \dfrac{12\text{ cm}^2}{4.0\text{ cm}} = 3.0\text{ cm}$

APPLIED CONCEPTS

1. The distance between New York City and London is 3470 mi. (a) If a radio wave from New York City is transmitted directly across the ocean, how long will it take to reach a receiver in London? (b) In fact, due to the curvature of the earth, radio waves cannot be transmitted directly across such large distances on the earth. Instead, a signal is typically transmitted to a communications satellite located 2.20×10^4 mi above the surface of the earth. If the satellite is located midway between the two cities, how long will the radio wave take to reach London? (Disregard the effect that the curvature of the earth has on the calculations.)
2. (a) When the Apollo astronauts landed on the moon, it took the radio signal 1.28 s to reach Mission Control on the earth. How far away were the astronauts from the earth? (b) Since the sun is 1.50×10^{11} m from the earth, how much time does it take for light to travel from the sun to the earth? (c) Light from our next-closest star, Alpha Centauri, takes 4.31 years to reach the earth. How far away from the earth is Alpha Centauri?
3. The range of electromagnetic wave frequencies on the FM radio band is 88.0 MHz to 108 MHz. (a) What is the range of wavelengths for the FM radio band? (b) What is the range of photon energy for the FM radio band? (c) Explain the relationship between frequency and photon energy.
4. The individual rods on rooftop antennas are designed to be one quarter of a wavelength for each television frequency. What is the range of rod lengths needed for television Channels 2 through 6 if their frequencies are between 54.0 MHz and 88.0 MHz?
5. An illumination of 180 lux on student desks and other work areas is the standard that architects use when designing lighting systems for schools. (a) If a ceiling is 2.50 m above a student work area, what intensity light source must be installed? (b) If the ceiling were twice its original height, what light intensity would be needed to meet the standard requirement?

Applied Concepts

Application-based questions at the end of each chapter develop problem-solving skills in real-life physics applications.

(*Continued from page ix.*)

- Physics Connections features apply physics to familiar real-world situations and events. These brief readings help students bridge the gap between what is taught in the chapter and real-world technical applications.
- Applied Concepts features provide application-based questions at the end of chapters that develop problem-solving skills in real-life physics applications.
- There is comprehensive discussion and consistent use of the results of working with measurements and significant digits.
- Biographical sketches of important scientists appear in most chapters.
- Answers to odd-numbered problems within the chapters and all chapter review questions and problems are given in Appendix F.
- A comprehensive glossary is given as a one-stop reference in Appendix E.
- Basic scientific calculator instructions are presented in Appendix D.
- A basic math review provides students with a refresher of the mathematics needed for this course in Appendix A.

Ancillaries

- Online Instructor's Manual
- Online PowerPoints
- Online Test Generator

Download Instructor Resources from the Instructor Resource Center

To access supplementary materials online, instructors need to request an instructor access code. Go to **www.pearsonhighered.com/irc** to register for an instructor access code. Within 48 hours of registering, you will receive a confirming e-mail, including an instructor access code. Once you have received your code, locate our text in the online catalog and click on the Instructor Resources button on the left side of the catalog product page. Select a supplement, and a login page will appear. Once you have logged in, you can access instructor material for all Pearson Education textbooks. If you have any difficulties accessing the site or downloading a supplement, please contact Customer Service at **247pearsoned.custhelp.com**.

To the Faculty

This text is written at a language level and at a mathematics level that is cognizant of and beneficial to *most* students in programs that do not require a high level of mathematics. The authors have assumed that the student has successfully completed one year of high school algebra or its equivalent. Simple equations and formulas are reviewed and any mathematics beyond this level is developed in the text or in an appendix. For example, right-triangle trigonometry is developed in Appendix A.5 for those who have not studied it previously or who need a review. The manner in which the mathematics is used in the text displays the need for mathematics in technology. For the better-prepared student, the mathematics sections may be omitted with no loss in continuity. This text is designed so that faculty have flexibility in selecting the topics, as well as the order of topics, that meet the needs of their students and programs of study.

Sections are short, and each deals with only one concept. The need for the investigation of a physical principle is developed before undertaking its study, and many diagrams are used to aid students in visualizing the concept. Many examples and problems are given to help students develop and check their mastery of one concept before moving to another.

This text is designed to be used in a vocational–technical program in a community college, a technical institute, or a high school for students who plan to pursue a technical career or in a general physics course where an applied physics approach is preferred. The topics were chosen with the assistance of technicians and management in several industries and faculty consultants. Suggestions from users and reviewers of the previous edition were used extensively in this edition.

A general introduction to physics is presented in Chapter 0. Chapter 1 introduces students to basic units of measurement. For students who lack a metric background or who need a review, an extensive discussion of the metric system is given in Chapter 1, where it is shown how the results of measurements are approximate numbers, which are then used consistently throughout the text. Those who need to review some mathematical skills are referred to the appendices as necessary. Chapter 2 introduces students to a problem-solving method that is consistently used in the rest of the text. Vectors are developed in Chapter 3, followed by a comprehensive study of motion, force, work and energy, rotational energy, simple machines, and universal gravitation and satellite motion.

The treatment of matter includes a discussion of the three states of matter, density, fluids, pressure, and Pascal's principle. The treatment of heat includes temperature, specific heat, thermal expansion, change of state, and ideal gas laws.

The section on wave motion and sound deals with basic wave characteristics, the nature and speed of sound, the Doppler effect, and resonance.

The section on electricity and magnetism begins with a brief discussion of static electricity, followed by an extensive treatment of dc circuits and sources, Ohm's law, and series and parallel circuits. The chapter on magnetism, generators, and motors is largely descriptive, but it allows for a more in-depth study if desired. Then ac circuits and transformers are treated extensively.

The chapter on light briefly discusses the wave and particle nature of light, but deals primarily with illumination. The chapter on reflection and refraction treats the images formed by mirrors and lenses. A brief introduction to color includes diffraction, interference, and polarization of light.

The section on modern physics provides an introduction to the structure and properties of the atomic nucleus, radioactive decay, nuclear reactions, and radioactivity, followed by a very brief introduction to relativity.

An Online Instructor's Manual that includes Complete Solutions, Transparency Masters, and a Test Item File is available at no charge to instructors using this text.

To the Student: Why Study Physics?

Physics is useful. Architects, mechanics, builders, carpenters, electricians, plumbers, and engineers are only some of the people who use physics every day in their jobs or professions. In fact, every person uses physics principles every hour of every day. The movement of an arm can be described using principles of the lever. All building trades, as well as the entire electronics industry, also use physics.

Physics is often defined as the study of matter, energy, and their transformations. The physicist uses scientific methods to observe, measure, and predict physical events and behaviors. However, gathered data left in someone's notebook in a laboratory are of little use to society.

Physics provides a universal means of describing and communicating about physical phenomena in the language of mathematics. Mechanics is the base on which almost all other areas of physics are built. Motion, force, work, electricity, and light are topics confronted daily in industry and technology. The basic laws of conservation of energy are needed to understand heat, sound, wave motion, electricity, and electromagnetic radiation.

Physics is always changing as new frontiers are being established in the study of the nature of matter. The topics studied in this course, however, will probably not greatly change with new research and will remain a classical foundation for work in many, many fields. We begin our study with the rules of the road—measurement, followed by a systematic problem-solving method. The end result should be a firm base on which to build a career in almost any field.

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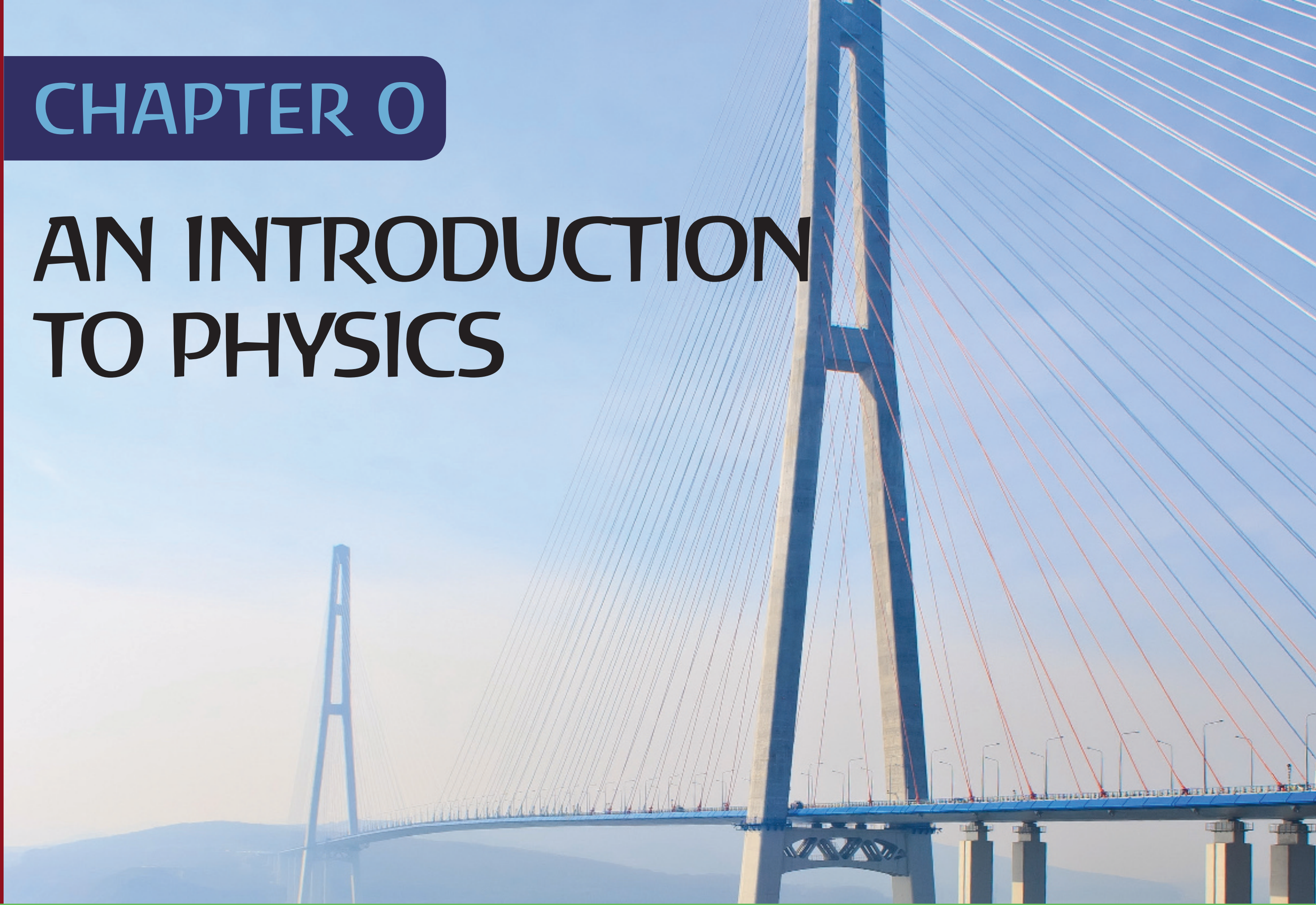
Dale Ewen
Neill Schurter
P. Erik Gundersen

CHAPTER 0

AN INTRODUCTION TO PHYSICS



Objectives

The major goals of this chapter are to enable you to:

1. Determine what physics governs and controls.
2. Conclude that physics is a building block of all the sciences.
3. Identify areas in your life that will be impacted by studying physics.
4. Differentiate between laws and theories.
5. Provide reasons why problem-solving techniques are vital in the study of physics.

Physics plays an important role in all aspects of our lives. Before enrolling in a physics course, you may have taken physics for granted. In this chapter we will introduce physics to you and help you appreciate the impact that physics will have on your life and career.

0.1 Why Study Physics?

What do flying birds, automobiles, blue skies, and cellular phones have in common? They all involve physics. **Physics** is the branch of science that describes the motion and energy of all matter throughout the universe. Birds, for example, use the difference in air pressures above and below their wings to keep themselves aloft. Automobiles use the principles of mechanics and thermodynamics to transfer stored chemical energy in gasoline to moving energy in rotating tires. The sky appears blue when sunlight strikes and scatters off nitrogen and oxygen molecules in our atmosphere. Finally, cellular phones use electronic components and the principles of electromagnetic waves to transfer energy and information from one cellular phone to another (Fig. 0.1).

Figure 0.1 Physics is involved in all aspects of cellular phone technology. It controls everything from the electrical circuits in the phone to the transmission of radio waves between phones.

Physics is often considered to be the most fundamental of all the sciences. In order to study biology, chemistry, or any other natural science, one should have a firm understanding of the principles of physics. For example, **biology,** the branch of science that studies living organisms, uses the physics principles of fluid movement to understand how the blood flows through the heart, arteries, and veins. **Chemistry,** the branch of science that studies the composition, structure, properties, and reactions of matter, relies on the physics of subatomic particles to understand why chemical reactions take place. **Geology,** the branch of science that studies the origin, history, and structure of the earth, uses the physics of mechanical waves and energy transfer to determine the magnitude and location of earthquakes. Finally, **astronomy,** the field of science that studies everything that takes place outside the earth's atmosphere, relies on the laws of gravity and theory of relativity to describe the workings of the universe.

Students often wonder, "Why should I study physics? What is it going to do for me?" The answer is that physics plays an important role in everyday life and in the careers of many people. Choosing the right bat, golf club, or ski can be made easier with a bit of physics knowledge (Fig. 0.2). While on the job, architects, engineers, electricians, medical technicians, surveyors, and others use the principles of physics every day. When understood, physics can help us solve difficult physical problems and be better decision makers to determine the best design, tool, or process when working on a specific task.

A **physicist** is a person who is an expert in or who studies physics. It is a physicist's job to seek an understanding of how the physical universe behaves. Albert Einstein, perhaps one of the most famous physicists of all time, once said, "I am like a child, I always ask the simplest questions" (Fig. 0.3). Such **theoretical physicists** often spend their professional lives researching previous theories and mathematical models to form new theories in physics. **Experimental physicists,** however, focus on performing experiments to develop and confirm physical theories.

It is generally accepted that physics evolved from ancient Greek philosophers, including Plato (c. 428–347 BC) and Aristotle (384–322 BC). Aristotle believed that there were two types of motion: Natural motion occurred because objects wanted to seek their "natural" resting place (smoke rising or rocks falling), whereas violent motion occurred when objects were unnaturally pulled or dragged from place to place (person dragging a crate). Although he was not correct in his analysis, it was the beginning of observing and documenting physical phenomena. Plato, Aristotle, and others like them can be considered theoretical physicists.

It was not until the days of Archimedes (287–212 BC) that experiments were conducted to document and prove physical theories (Fig. 0.4). Since then, a vast number of physicists have built and improved upon the knowledge base developed by those before them. It is now your turn to use the physics that you will learn to help you understand, improve, and make advances in our technological world. You will see that physics has use!

TRY THIS ACTIVITY

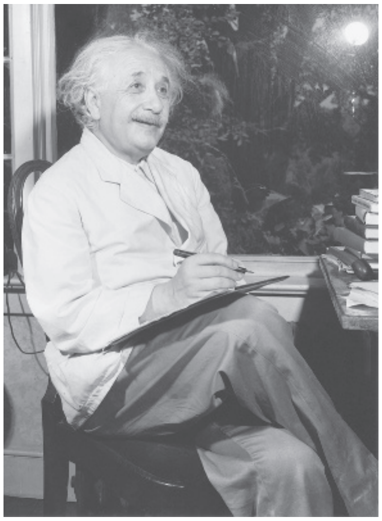
Physics All Around Us

Look around and find something that may have to do with physics. Although you may not yet have studied many physics principles, you should know that physics governs things that move and transfer energy. Be as general as you need to be in your observations. The point is for you to see that physics plays a role in almost everything.

Figure 0.2 A baseball player's understanding of physics can help improve all aspects of his game, including pitching, batting, and fielding.

Courtesy of fotolia ©Paul Yates

Figure 0.3 Albert Einstein (1879–1955) is often considered one of the most influential scientists of the 20th century. His work on relativity, as made famous through the equation $E = mc^2$, and the photoelectric effect changed the way the world viewed physics.



Courtesy of National Archives and Records Administration

Figure 0.4 Archimedes is best known for observing that water was displaced when he stepped into his bath. He proceeded to conduct experiments where he measured the amount of water that overflowed when objects were placed into a tub full of water. He established a principle that states that an object immersed in a fluid will experience a buoyant force equal to the weight of the displaced fluid. Archimedes is also recognized for his work with simple machines like the screw, lever, and pulley. Legend has it that Archimedes said, "Give me a firm spot on which to stand and I will move the earth" (referring to the use of a lever).

Courtesy of fotolia ©Erica Guilane-Nachez

0.2 Physics and Its Role in Technology

Although often discussed as though they are the same thing, science and technology are quite different. **Science** is a system of knowledge that is concerned with establishing accurate conclusions about the behavior of everything in the universe. It is a field in which **hypotheses** (scientifically based predictions) are made, information is gathered, and experiments are performed to determine how something in our natural world works or behaves. **Technology,** on the other hand, is a field that uses scientific knowledge to develop material products or processes that satisfy human needs and desires. Technology and science rely closely on one another to make further advances in their respective fields.

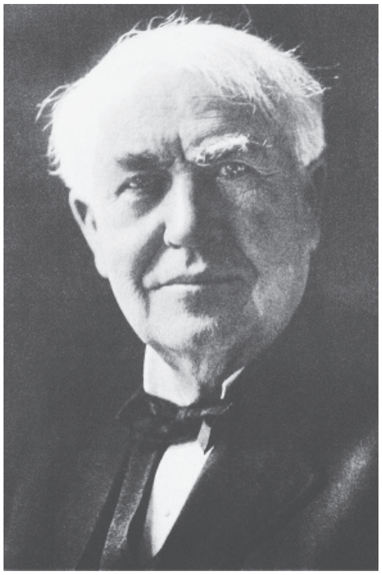
Thomas A. Edison (1847–1931) used scientific information and the discoveries of other scientists to create over 1000 inventions (Fig. 0.5). Edison's development of the first practical lighting system was made possible by applying the science of electricity and the science of materials and then putting that knowledge to use to satisfy his technological need.

The following illustrate how science has played a role in improving technology.

Robotics: Due to advances in electronics, materials, and machines, robots commonly perform a variety of tasks from assembling cars on a production line to exploring the surface of Mars. NASA's Curiosity rover is used to travel remotely across the Martian surface collecting samples and relaying images and data back to scientists on earth (Fig. 0.6).

Bridges: Work in materials science and structural engineering has paved the way for advances in bridge design and construction. The New Clark Bridge in Alton, Illinois, is just one example of a cable-stayed bridge that has used

Figure 0.5 Thomas A. Edison



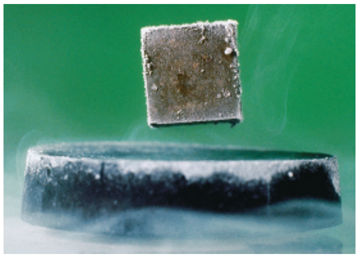
Courtesy of National Park Service, Edison National Historic Site

Figure 0.6 NASA's Curiosity Rover traveling toward the Mojave 2 region of the Martian surface in January 2015.

Courtesy of NASA

Figure 0.7 The New Clark Bridge, a cable-stayed bridge in Alton, Illinois.

Figure 0.8 A magnet levitates above a superconductor.



Courtesy of Brookhaven National Laboratory

scientific breakthroughs in materials science and physics to increase the structural integrity of the bridge and cut costs (Fig. 0.7).

Superconductors: Superconductors allow electric current to travel with virtually no resistance through materials. Materials such as aluminum, lead, and niobium are cooled by liquid helium to bring the temperature down to the low critical point. At the low critical point temperatures, the materials achieve zero electric resistance (Fig. 0.8). Scientific research is under way to develop superconducting materials that can operate closer to room temperature; this would bring about tremendous improvements in energy efficiency.

Active noise cancellation: Audiologists will tell you that noise increases stress levels. Acoustic and electrical engineers are now able to produce inverted noise patterns that cancel out disturbing noise (Fig. 0.9). Helicopter pilots, factory workers, and business travelers are using this technology to reduce stressful noise levels in their environment.

Liquid crystal displays: With advances in optics and electronics, physicists and chemists have created more advanced liquid crystal displays (LCDs), which are used as screens on laptop computers, cell phones, watches, and televisions (Fig. 0.10).

Magnetic levitation: The speed limitations of traditional trains have created a need for super-fast, magnetic levitation (maglev) trains (Fig. 0.11). Such a vehicle is levitated off a monorail by virtue of the magnetic repulsion between the train and the rail. Electromagnets are used to propel the train forward as it glides above the rail. Such improvements greatly reduce frictional resistance and allow trains to travel at twice the speed of conventional trains—up to 250 miles per hour.

Gyroscope: A gyroscope is a heavy wheel that uses rotational inertia to prevent tilting and is used to steady compasses, ships, airplanes, and rockets (Fig. 0.12). Advances in gyroscopes and electronic sensors have made it possible to create gyrostabilizers for ships. Such devices send signals to the ship's computer specifying how its fins should be positioned to prevent significant rolling motions.

Figure 0.9 Active noise cancellation technology for the consumer can be found in small, noise-reduction headsets.

Figure 0.10 Advances in LCD panels allow small electronic devices to have color screens.

Alternative fuels: The ever-increasing demand for energy, coupled with the earth's finite supply of fossil fuels, has led scientists and engineers to discover and develop additional sources of energy. Alternative sources include solar energy, wind energy (Fig. 0.13), hydropower, geothermal energy, hydrogen fuel cells, nuclear power, biofuel, and wave/tidal energy. Technological advances with regard to the efficiency of the various energy sources will lead to higher cost benefits and more widespread use of such alternative energy sources.

0.3 Physics and Its Connection to Other Fields and Sciences

Ancient Greeks like Plato and Aristotle did not specialize in physics. In fact, it was not until the 1800s that physics was considered a science. Prior to the 1800s, Plato, Aristotle, Copernicus, and Galileo were considered natural philosophers, not physicists. Today,

Figure 0.11 Maglev train technology has high-speed trains competing with airplane service.

Courtesy of U.S. Department of Transportation

Figure 0.12 Gyroscope

Courtesy of fotolia ©Gramper

Figure 0.13 Wind Turbines on a Texas countryside.

Courtesy of NASA

virtually every physicist specializes in a subdivision of physics. There is simply too much information to allow someone to study every type of physics.

The following is a listing of the 18 subdivisions of physics:

Mechanics: Study of forces, motion, and energy.
Thermodynamics: Study of heat energy transfer.
Cryogenics: Study of matter at extremely low temperatures.
Plasma physics: Study of electrically charged, ionized gas.
Solid state physics: Study of the physical properties of solid materials, also known as condensed matter physics.
Geophysics: Study of the interaction of forces and energy found within the earth; closely related to geology.
Astrophysics: Study of the interaction of forces and energy between interstellar objects; closely related to astronomy.
Acoustics: Study of the creation and transmission of sound under various conditions.
Optics: Study of the behavior of light in a variety of conditions.
Electromagnetism: Study of the relationship between electricity and magnetism.
Fluid dynamics: Study of how liquids and gases move from one location to another.
Mathematical physics: Study of the mathematics of physics and its related fields.
Statistical mechanics: Study of the development of statistical models that simulate the effects of systems composed of many particles.
High-energy physics: Study of new fundamental, subatomic particles using high-energy machines that send known subatomic particles colliding into one another; simulation of what the universe was like close to the time of the "big bang."
Atomic physics: Study of the structure of the atom based on the knowledge gained in the field of high-energy physics.
Molecular physics: Study of the structure of molecules based on the knowledge gained in atomic physics.
Nuclear physics: Study of nuclear interactions.
Quantum physics: Study of small particles and their energy.

0.4 Theories, Laws, and Problem Solving

Physics is constantly being refined. Although the major principles of physics do not change drastically over time, newer theories requiring a tremendous amount of experimentation can modify our understanding of physics. A **theory** is a scientific conclusion

PHYSICS CONNECTIONS

Physics, Technology, and Sports

Physics plays a major role in sports. From the padding in a baseball glove to the stance of a wrestler, a good working knowledge of physics helps athletes and sports equipment companies achieve greater successes. Ski companies employ engineers who focus solely on the physics and engineering of improving a skier's time down the mountain. At the Winter Olympics adjustments made to the length, shape, and composition of the skis play an important role in the success of the skiers. Such variables determine the amount of pressure the skier places on the snow and the friction of the ski. There are tradeoffs as well. Whereas a wider ski front increases its turning abilities, it also creates large vibrations that can slow down the skier. The use of titanium and various fibers and adhesives decreases those vibrations and results in lighter, stiffer skis. The application of physics has taken the once-simple wooden ski and has created a complex, high-performance device (Fig. 0.14).

Figure 0.14 Each ski design is created for use based on scientific knowledge.

Courtesy of fotolia ©Lulu Berlu

that attempts to explain natural occurrences. Typically it has been tested in the laboratory but has not been proven with absolute certainty. A **principle** is a step closer to a law in physics. Principles have been experimentally proven in the laboratory, have stood the test of various conditions, and continue to hold true. Laws are the final degree of scientific certainty. **Laws** are often defined using formulas. For example, Newton's second law of motion, $F = ma$, has been proven to be true and is considered a law of physics.

The **scientific method** is an orderly procedure used by scientists in collecting, organizing, and analyzing new information that refutes or supports a scientific hypothesis. The constant use of the scientific method and the development of theories, principles, and laws is similar to the problem-solving method discussed in detail in Chapter 2. The **problem-solving method** is an orderly procedure that aids in understanding questions and solving problems. Nonscientists use the problem-solving method more often than the scientific method. The problem-solving method is helpful when a problem arises in this text, in class, or on the job. An individual or a team must develop the skills needed to collect data, analyze a problem, and work toward finding its solution in a logical and orderly fashion. In order to find solutions to problems, tools are needed to make the job easier. In the next chapter, we will familiarize ourselves with two important tools of physics: measurement and mathematics.

Glossary

Astronomy The branch of science that studies everything that takes place outside the earth's atmosphere. (p. 2)

Biology The branch of science that studies living organisms. (p. 2)

Chemistry The branch of science that studies the composition, structure, properties, and reactions of matter. (p. 2)

Experimental Physicist A physicist who performs experiments to develop and confirm physical theories. (p. 2)

Geology The branch of science that studies the origin, history, and structure of the earth. (p. 2)

Hypothesis A scientifically based prediction that needs testing to verify its validity. (p. 3)

Law The highest level of certainty for an explanation of physical occurrences. A law is often accompanied by a formula. (p. 7)

Physics The branch of science that describes the motion and energy of all matter throughout the universe. (p. 1)

Physicist A person who is an expert in or who studies physics. (p. 2)

Principle A rule or fundamental assumption that has been proven in the laboratory. (p. 7)

Problem-Solving Method An orderly procedure that aids in understanding questions and solving problems. (p. 7)

Science A system of knowledge that is concerned with establishing accurate conclusions about the behavior of everything in the universe. (p. 3)

Scientific Method An orderly procedure used by scientists in collecting, organizing, and analyzing new information that refutes or supports a scientific hypothesis. (p. 7)

Technology The field that uses scientific knowledge to develop material products or processes that satisfy human needs and desires. (p. 3)

Theoretical Physicist A physicist who predominantly uses previous theories and mathematical models to form new theories in physics. (p. 2)

Theory A scientifically accepted principle that attempts to explain natural occurrences. (p. 7)

Review Questions

1. Physics is a field of study that governs
   (a) how the planets orbit the sun.
   (b) the rate at which blood flows through a person's veins.
   (c) how quickly a helium balloon will rise into the air.
   (d) all of the above.
2. Who among the following is an example of a theoretical physicist?
   (a) Archimedes, who measured the volume of water that was displaced after placing objects in a tub of water.
   (b) Albert Einstein, who performed various thought experiments in his mind to arrive at his theories of relativity.
   (c) Marie Curie, who, along with her husband, was credited with discovering radioactivity through a series of laboratory experiments.
   (d) Benjamin Franklin, who determined, through various laboratory experiments, that electricity is the flow of microscopic charged particles.
3. Why are Isaac Newton's conclusions on motion considered laws of physics?
   (a) Newton himself declared them laws.
   (b) Newton performed various thought experiments on motion.
   (c) The formulas accompanying Newton's laws have proved correct in experiments for years.
   (d) Newton's reputation alone made his scientific conclusions laws.
4. Which of the following is not considered a branch of physics?
   (a) Thermodynamics
   (b) Astronomy
   (c) Geophysics
   (d) Atomic physics

5. Analyzing the braking distance of a sports car would most likely utilize which field of physics?
   (a) Molecular physics
   (b) Quantum physics
   (c) Fluid dynamics
   (d) Mechanics
6. Who is considered to be the first true physicist and what did he do to deserve this recognition in scientific history?
7. Explain the difference between science and technology. Are the two fields related?
8. Provide two examples of scientific knowledge and a technological development that relies on that scientific knowledge.
9. What is the difference between the scientific method and the problem-solving method?
10. Why is it important to study physics? Provide a few examples of what an understanding of the physical world can do for you today and in your future.