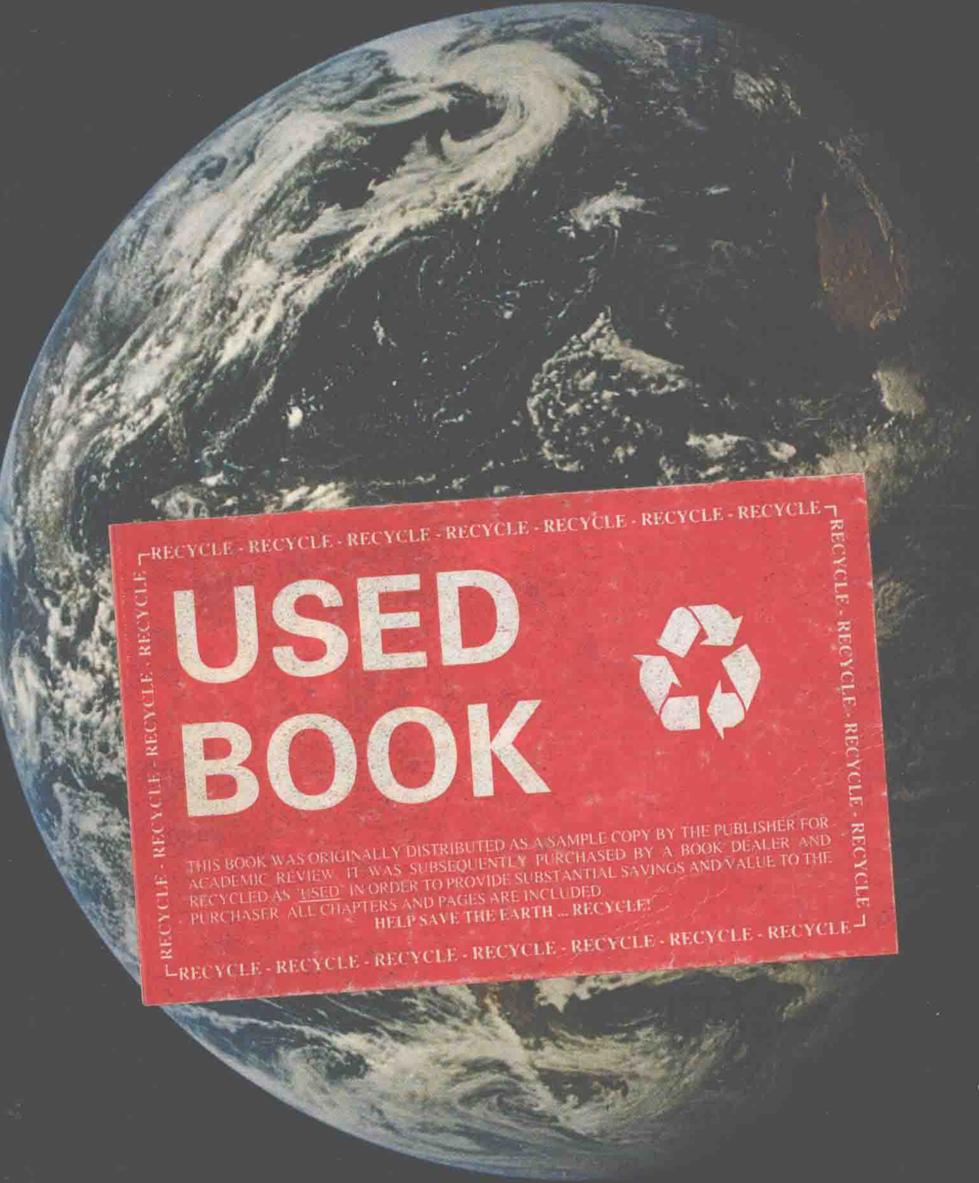
Fundamentals of
PHYSICAL SCIENCE



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FUNDAMENTALS OF PHYSICAL SCIENCE

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To Kent Porter Hamann
for her insight and leadership in
the overall development of this text.

Cover and title page: The *Apollo 15* crew shot this photograph of their home planet from between 25,000 and 30,000 nautical miles away as they sped toward the fourth moon landing by voyagers from Earth. The United States, Central America, and part of Canada can be seen at the left side, with South America at lower center. Spain and the northwest part of Africa are at the right. The bright blue spot of the Bahama Banks, a unique geological feature, can be seen southeast of Florida. Note the large North Atlantic storm front moving over Greenland in upper center. (NASA/Johnson Space Center)

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PREFACE

In this technological society, it is imperative that we as educators stimulate student interest in the sciences and present the information and skills students need to cope in today's world. In *Fundamentals of Physical Science,* we make concepts easily accessible by developing them in a logical rather than a chronological fashion and by discussing them in the context of everyday experience. We provide real-world examples of physical science throughout the text to enhance the students' understanding of their natural world.

Fundamentals of Physical Science, designed for the first-year college nonscience major, emphasizes the basic concepts in physics, chemistry, and astronomy and presents an overview of meteorology and geology. Because many courses cover only physics, chemistry, and perhaps astronomy, we have chosen to concentrate our efforts in those areas of physical science; however, we do provide broad-brush coverage of meteorology and geology for courses that present more of a survey of physical science.

The most outstanding feature of *Fundamentals of Physical Science* is the pedagogy in every chapter (see Focus on Problem-Solving on p. xv). First, wherever appropriate, we provide a step-by-step approach for solving problems in the chapter. These steps are highlighted for quick reference. Next, we solve each in-text example step by step so that students can easily follow how the problem-solving approach is applied. Then, we present Confidence Exercises and Confidence Questions that enable students to check their understanding of the preceding material before moving on to the next section. Answers to the Confidence Exercises and Questions are provided at the end of each chapter.

Fundamentals is structured to facilitate student involvement in the material. Care has been taken to move logically through each chapter, problem, and worked-out solution without skipping steps and leaving the student confused. Chapter 1 begins with the fundamental concepts of measurement. From these fundamentals, we move on progressively to the concepts of motion, force, energy, wave motion, heat, electricity, magnetism, and modern physics. These concepts are then used to develop the principles of chemistry and astronomy.

We have treated each discipline both descriptively and quantitatively. Even though we have provided mathematical assistance for those students who may need it the most, the relative emphasis, whether descriptive or quantitative, is left to the discretion of the instructor. To those who wish to emphasize the descriptive approach in teaching physical science, we recommend using only the Questions at the end of each chapter and omitting the Exercises.

Supplements

- The *Study Guide,* by James T. Shipman of Ohio University, Jerry D. Wilson of Lander College, and Clyde D. Baker, also of Ohio University. Each chapter includes study goals, discussion, review questions, solved problems, multiple-choice questions with explanations, and a quiz. There is also a math review at the end of the *Study Guide.*
- The *Instructor's Guide* and *Test Item File,* by James T. Shipman and Jerry D. Wilson, have been combined into one supplement for convenience. Each chapter of the *Instructor's Guide* includes a brief discussion, suggested demonstrations, answers to text questions and solutions for exercises, and answers to the *Study Guide* quizzes. The *Test Item File* offers a printed version of more than 1600 questions available in completion, multiple-choice, and short exercise formats. The Appendix includes a Teaching Aids section for each of the five sciences and up-to-date audiovisual resources.
- The *Laboratory Guide,* by James T. Shipman, contains a total of 47 experiments. Each experiment includes an introduction, learning objectives, a list of required apparatus, a detailed procedure for collecting data (requiring students to generate tables and graphs and to perform calculations), and questions about the experiment.

- The *Instructor's Resource Manual for the Laboratory Guide,* also by James T. Shipman, now includes an integrated equipment list to assist instructors in planning experiments. Additional data and calculations are provided for most experiments, as well as answers to questions, a discussion of each experiment, and additional questions. The *Laboratory Guide* and the *Instructor's Resource Manual for the Laboratory Guide* are appropriate for courses using either *Fundamentals* or the Sixth Edition of *Introduction to Physical Science.*
- The Test *Item File* questions are available in a computerized testing program. Instructors can produce chapter tests, midterms, and final exams, with graphics, easily. Instructors may edit existing questions or add new ones as desired and preview questions on screen. The computerized testing program is available for IBM and Macintosh computers.
- The Transparencies—68 one-, two-, and four-color—illustrate important concepts from the text. They are available to adopters of either *Fundamentals of Physical Science* or *Introduction to Physical Science,* Sixth Edition.

Acknowledgments

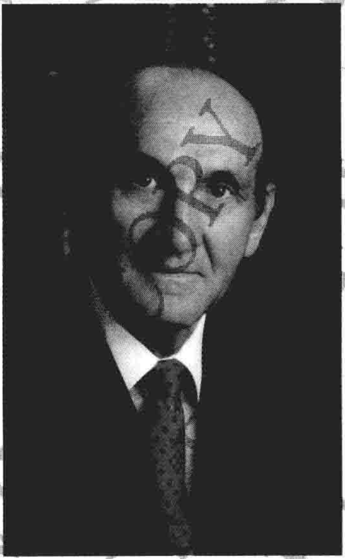
The authors wish to thank our colleagues and students for the many contributions they made to this text through correspondence, discussions, questionnaires, and classroom use of the text material. We would also like to thank the following reviewers for their suggestions and comments: Stephen R. Addison, University of Central Arkansas; Richard M. Bowers, Weatherford College; Susan G. Burlingham Arnold, formerly Pratt Community College; Robert W. Childers, Tulsa Junior College; Donald E. Dalrymple, North Central Missouri College; Paul D. Lee, Louisiana State University; L. Whit Marks, Central State University; Eugene D. Miller, Luzerne County Community College; J. Ronald Mowry, Harrisburg Area Community College; R. H. Orcutt, East Tennessee State University; Charles Ostrander, Hudson Valley Community College; Surendra N. Pandey, Albany State College; Harry D. Powell, East Tennessee State University; Pushpa Ramakrishna, formerly Chandler Gilbert Community College; Thomas G. Read, Martin Methodist College; John E. Rives, University of Georgia; David Robertson, Alcorn State University; Aaron W. Todd, Middle Tennessee State University; Alan Ziv, Arizona State University.

We are grateful to those individuals and organizations who contributed photographs, illustrations, and other information used in this text. We are also indebted to the D. C. Heath staff for their dedicated and conscientious efforts in the production of *Fundamentals of Physical Science.* We want to give special thanks to Kent Porter Hamann, Editorial Director, for her continued leadership and publishing vision. We also wish to thank Barbara Withington Meglis, Developmental Editor; Bryan Woodhouse and Cathy Brooks, Production Editors; Henry Rachlin, Designer; and Susan Doheny, Photo Researcher. Finally, we acknowledge the contributions of Geoffrey W. Smith, Ohio University; Genny Shipman, and Sandy Wilson.

We welcome comments from students and instructors of physical science and invite you to send your impressions and suggestions.

J. T. S.
J. D. W.

ABOUT THE AUTHORS



After serving in the U.S. Navy during World War II, **James T. Shipman** attended Ohio University. He received his B. S. and M. S. degrees from Ohio and an honorary Ph.D. from Chubu University in Japan. For 25 years, he taught physics and physical science at Ohio, where he was also Department Chair for five years (1968-73). He has also taught physics and/or physical science at Clark College, Fairmont State College, and Salem-Teikyo University.

Professor Shipman has received and served as director of several National Science Foundation education grants. His research activities have included studies of cosmic rays, ionospheric radio-propagation, and high-frequency radio tracking. He is a member of the American Association of Physics Teachers, and he has served as president of the Appalachian Section. He has written a number of other books, including *Introduction to Physical Science, Concepts of Modern Physics and Chemistry*, and the *Physical Science Laboratory Guide.* A translation of the physics section of *An Introduction to Physical Science* is currently used in Japan.

Doctor Shipman is now Professor Emeritus of Physics at Ohio University, where he remains active in writing and continues an active role. He serves on the National Campaign Council. He is now semiretired and living in West Virginia, his native state.

Jerry D. Wilson, a native of Ohio, is Professor of Physics and Chair of the Division of Biological and Physical Sciences at Lander College in Greenwood, South Carolina. He received his B.S. from Ohio University, a M.S. from Union College, and in 1970 a Ph.D. from Ohio University. As a doctoral graduate student, he taught physical science and held the faculty rank of Instructor. He wrote his portion of the text *An Introduction to Physical Science* at that time. The text, now in its sixth edition, was originally published locally in three sections before being published nationally *in toto* in 1971 by D. C. Heath and Company.

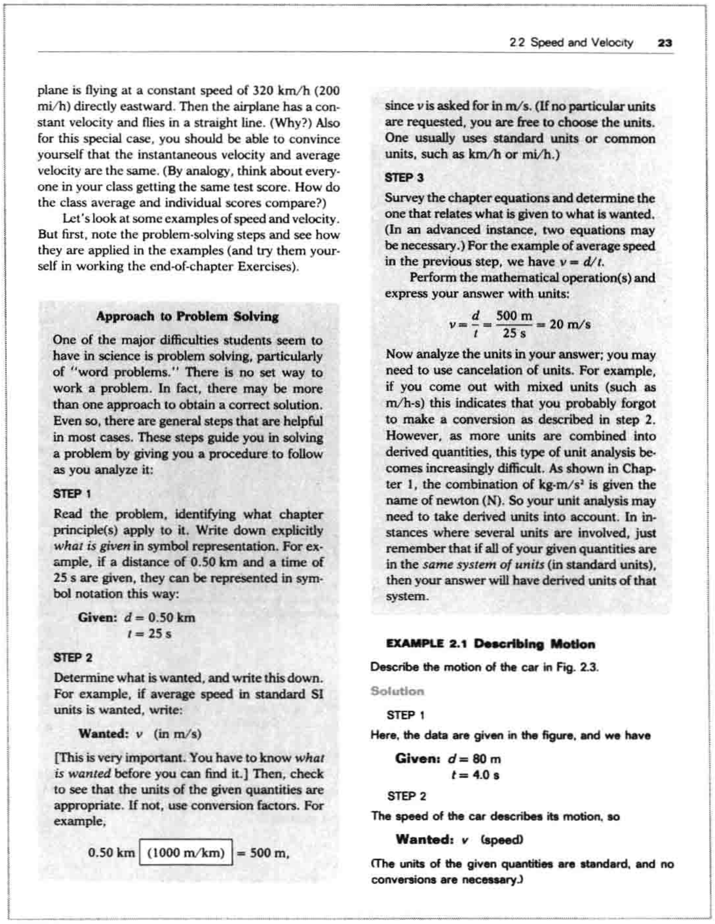
Being primarily interested in science teaching, Dr. Wilson has continued to write and currently has three other texts and a laboratory manual in publication in various editions—*Physics: A Practical and Conceptual Approach, Technical College Physics*, and *College Physics.* His popular laboratory manual, *Physics Laboratory Experiments*, published by D. C. Heath, is now in its third edition. He has also written articles for professional journals and presented a number of papers at various scientific-organization meetings. In his spare time (of which there is little), he writes a weekly column, The Science Corner, for local newspapers.

FOCUS ON PROBLEM SOLVING

A Note from the Authors: In *Fundamentals of Physical Science,* we've tried to pay particular attention to helping students solve problems. In the following examples, we point out some of the unique features in *Fundamentals* that will help students think logically when approaching a problem, guide them through the solution in a step-by-step fashion, and provide additional questions and problems to master the concepts just presented.

We hope you'll find these features useful as you proceed through *Fundamentals of Physical Science.* If there are additional ways we can enhance learning, we'd be pleased to hear from you.

Suggested procedures and strategies for solving problems logically are highlighted in green for easy student reference. ⟶



2.2 Speed and Velocity **23**

plane is flying at a constant speed of 320 km/h (200 mi/h) directly eastward. Then the airplane has a constant velocity and flies in a straight line. (Why?) Also for this special case, you should be able to convince yourself that the instantaneous velocity and average velocity are the same. (By analogy, think about everyone in your class getting the same test score. How do the class average and individual scores compare?)

Let's look at some examples of speed and velocity. But first, note the problem-solving steps and see how they are applied in the examples (and try them yourself in working the end-of-chapter Exercises).

Approach to Problem Solving

One of the major difficulties students seem to have in science is problem solving, particularly of "word problems." There is no set way to work a problem. In fact, there may be more than one approach to obtain a correct solution. Even so, there are general steps that are helpful in most cases. These steps guide you in solving a problem by giving you a procedure to follow as you analyze it:

STEP 1

Read the problem, identifying what chapter principle(s) apply to it. Write down explicitly *what is given* in symbol representation. For example, if a distance of 0.50 km and a time of 25 s are given, they can be represented in symbol notation this way:

Given: $d = 0.50$ km
$t = 25$ s

STEP 2

Determine what is wanted, and write this down. For example, if average speed in standard SI units is wanted, write:

Wanted: v (in m/s)

[This is very important. You have to know *what is wanted* before you can find it.] Then, check to see that the units of the given quantities are appropriate. If not, use conversion factors. For example,

$$0.50\ \text{km}\ \boxed{(1000\ \text{m/km})} = 500\ \text{m},$$

since v is asked for in m/s. (If no particular units are requested, you are free to choose the units. One usually uses standard units or common units, such as km/h or mi/h.)

STEP 3

Survey the chapter equations and determine the one that relates what is given to what is wanted. (In an advanced instance, two equations may be necessary.) For the example of average speed in the previous step, we have $v = d/t$.

Perform the mathematical operation(s) and express your answer with units:

$$v = \frac{d}{t} = \frac{500\ \text{m}}{25\ \text{s}} = 20\ \text{m/s}$$

Now analyze the units in your answer; you may need to use cancelation of units. For example, if you come out with mixed units (such as m/h-s) this indicates that you probably forgot to make a conversion as described in step 2. However, as more units are combined into derived quantities, this type of unit analysis becomes increasingly difficult. As shown in Chapter 1, the combination of kg-m/s^2 is given the name of newton (N). So your unit analysis may need to take derived units into account. In instances where several units are involved, just remember that if all of your given quantities are in the *same system of units* (in standard units), then your answer will have derived units of that system.

EXAMPLE 2.1 Describing Motion

Describe the motion of the car in Fig. 2.3.

Solution

STEP 1

Here, the data are given in the figure, and we have

Given: $d = 80$ m
$t = 4.0$ s

STEP 2

The speed of the car describes its motion, so

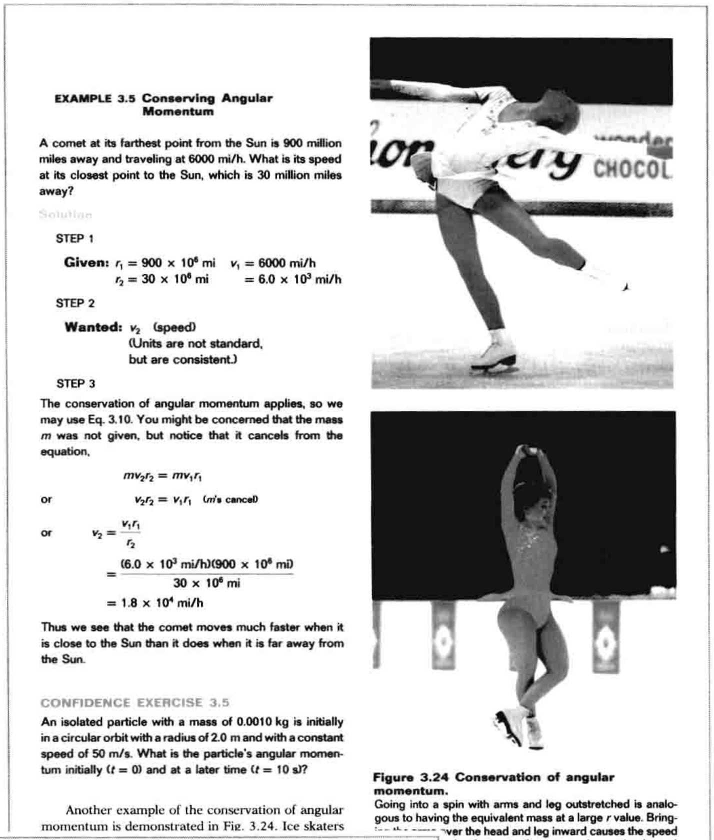
Wanted: v (speed)

(The units of the given quantities are standard, and no conversions are necessary.)

Examples are labeled for easy student reference. →

Clear step-by-step solutions are provided to in-text examples. →

Confidence Exercises provide immediate reinforcement of students' understanding of the material just covered. →



EXAMPLE 3.5 Conserving Angular Momentum

A comet at its farthest point from the Sun is 900 million miles away and traveling at 6000 mi/h. What is its speed at its closest point to the Sun, which is 30 million miles away?

Solution

STEP 1

Given: $r_1 = 900 \times 10^6$ mi $\quad v_1 = 6000$ mi/h
$r_2 = 30 \times 10^6$ mi $\quad = 6.0 \times 10^3$ mi/h

STEP 2

Wanted: v_2 (speed)
(Units are not standard, but are consistent.)

STEP 3

The conservation of angular momentum applies, so we may use Eq. 3.10. You might be concerned that the mass *m* was not given, but notice that it cancels from the equation,

$$mv_2r_2 = mv_1r_1$$

or

$$v_2r_2 = v_1r_1 \quad (m\text{'s cancel})$$

or

$$v_2 = \frac{v_1r_1}{r_2} = \frac{(6.0 \times 10^3 \text{ mi/h})(900 \times 10^6 \text{ mi})}{30 \times 10^6 \text{ mi}} = 1.8 \times 10^4 \text{ mi/h}$$

Thus we see that the comet moves much faster when it is close to the Sun than it does when it is far away from the Sun.

CONFIDENCE EXERCISE 3.5

An isolated particle with a mass of 0.0010 kg is initially in a circular orbit with a radius of 2.0 m and with a constant speed of 50 m/s. What is the particle's angular momentum initially ($t = 0$) and at a later time ($t = 10$ s)?

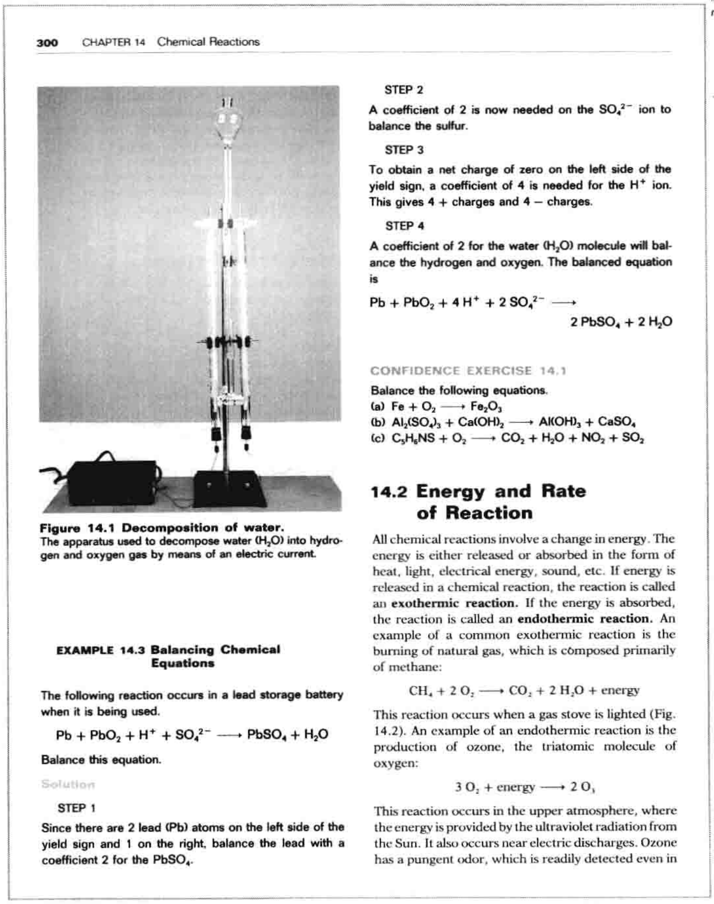
Another example of the conservation of angular momentum is demonstrated in Fig. 3.24. Ice skaters

Figure 3.24 Conservation of angular momentum.
Going into a spin with arms and leg outstretched is analogous to having the equivalent mass at a large *r* value. Bring-
ver the head and leg inward causes the speed
nd a fast spin (but not a change in skaters)

Here's another labeled example, this one from chemistry, showing the step-by-step problem solving approach. →

← **A Confidence Exercise follows to check mastery of the material.**

Students can check their solutions to the Confidence Exercises at the end of the chapter.



300 CHAPTER 14 Chemical Reactions

Figure 14.1 Decomposition of water.
The apparatus used to decompose water (H_2O) into hydrogen and oxygen gas by means of an electric current.

EXAMPLE 14.3 Balancing Chemical Equations

The following reaction occurs in a lead storage battery when it is being used.

$$Pb + PbO_2 + H^+ + SO_4^{2-} \longrightarrow PbSO_4 + H_2O$$

Balance this equation.

Solution

STEP 1

Since there are 2 lead (Pb) atoms on the left side of the yield sign and 1 on the right, balance the lead with a coefficient 2 for the $PbSO_4$.

STEP 2

A coefficient of 2 is now needed on the SO_4^{2-} ion to balance the sulfur.

STEP 3

To obtain a net charge of zero on the left side of the yield sign, a coefficient of 4 is needed for the H^+ ion. This gives 4 + charges and 4 − charges.

STEP 4

A coefficient of 2 for the water (H_2O) molecule will balance the hydrogen and oxygen. The balanced equation is

$$Pb + PbO_2 + 4\,H^+ + 2\,SO_4^{2-} \longrightarrow 2\,PbSO_4 + 2\,H_2O$$

CONFIDENCE EXERCISE 14.1

Balance the following equations.
(a) $Fe + O_2 \longrightarrow Fe_2O_3$
(b) $Al_2(SO_4)_3 + Ca(OH)_2 \longrightarrow Al(OH)_3 + CaSO_4$
(c) $C_5H_5NS + O_2 \longrightarrow CO_2 + H_2O + NO_2 + SO_2$

14.2 Energy and Rate of Reaction

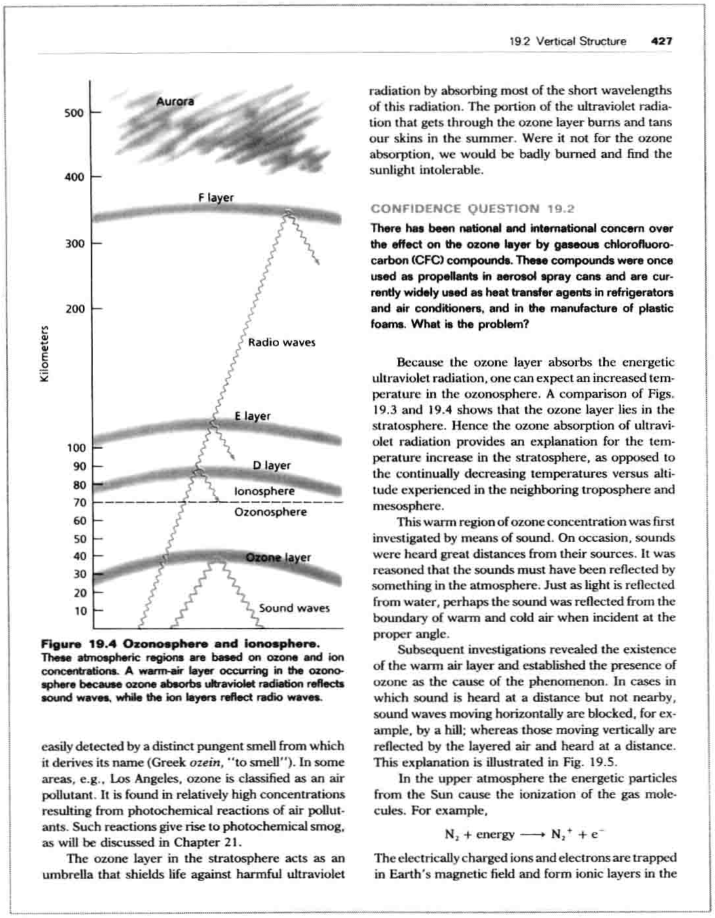
All chemical reactions involve a change in energy. The energy is either released or absorbed in the form of heat, light, electrical energy, sound, etc. If energy is released in a chemical reaction, the reaction is called an **exothermic reaction.** If the energy is absorbed, the reaction is called an **endothermic reaction.** An example of a common exothermic reaction is the burning of natural gas, which is composed primarily of methane:

$$CH_4 + 2\,O_2 \longrightarrow CO_2 + 2\,H_2O + \text{energy}$$

This reaction occurs when a gas stove is lighted (Fig. 14.2). An example of an endothermic reaction is the production of ozone, the triatomic molecule of oxygen:

$$3\,O_2 + \text{energy} \longrightarrow 2\,O_3$$

This reaction occurs in the upper atmosphere, where the energy is provided by the ultraviolet radiation from the Sun. It also occurs near electric discharges. Ozone has a pungent odor, which is readily detected even in



19.2 Vertical Structure 427

Figure 19.4 Ozonosphere and ionosphere. These atmospheric regions are based on ozone and ion concentrations. A warm-air layer occurring in the ozonosphere because ozone absorbs ultraviolet radiation reflects sound waves, while the ion layers reflect radio waves.

easily detected by a distinct pungent smell from which it derives its name (Greek *ozein*, "to smell"). In some areas, e.g., Los Angeles, ozone is classified as an air pollutant. It is found in relatively high concentrations resulting from photochemical reactions of air pollutants. Such reactions give rise to photochemical smog, as will be discussed in Chapter 21.

The ozone layer in the stratosphere acts as an umbrella that shields life against harmful ultraviolet radiation by absorbing most of the short wavelengths of this radiation. The portion of the ultraviolet radiation that gets through the ozone layer burns and tans our skins in the summer. Were it not for the ozone absorption, we would be badly burned and find the sunlight intolerable.

CONFIDENCE QUESTION 19.2

There has been national and international concern over the effect on the ozone layer by gaseous chlorofluorocarbon (CFC) compounds. These compounds were once used as propellants in aerosol spray cans and are currently widely used as heat transfer agents in refrigerators and air conditioners, and in the manufacture of plastic foams. What is the problem?

Because the ozone layer absorbs the energetic ultraviolet radiation, one can expect an increased temperature in the ozonosphere. A comparison of Figs. 19.3 and 19.4 shows that the ozone layer lies in the stratosphere. Hence the ozone absorption of ultraviolet radiation provides an explanation for the temperature increase in the stratosphere, as opposed to the continually decreasing temperatures versus altitude experienced in the neighboring troposphere and mesosphere.

This warm region of ozone concentration was first investigated by means of sound. On occasion, sounds were heard great distances from their sources. It was reasoned that the sounds must have been reflected by something in the atmosphere. Just as light is reflected from water, perhaps the sound was reflected from the boundary of warm and cold air when incident at the proper angle.

Subsequent investigations revealed the existence of the warm air layer and established the presence of ozone as the cause of the phenomenon. In cases in which sound is heard at a distance but not nearby, sound waves moving horizontally are blocked, for example, by a hill; whereas those moving vertically are reflected by the layered air and heard at a distance. This explanation is illustrated in Fig. 19.5.

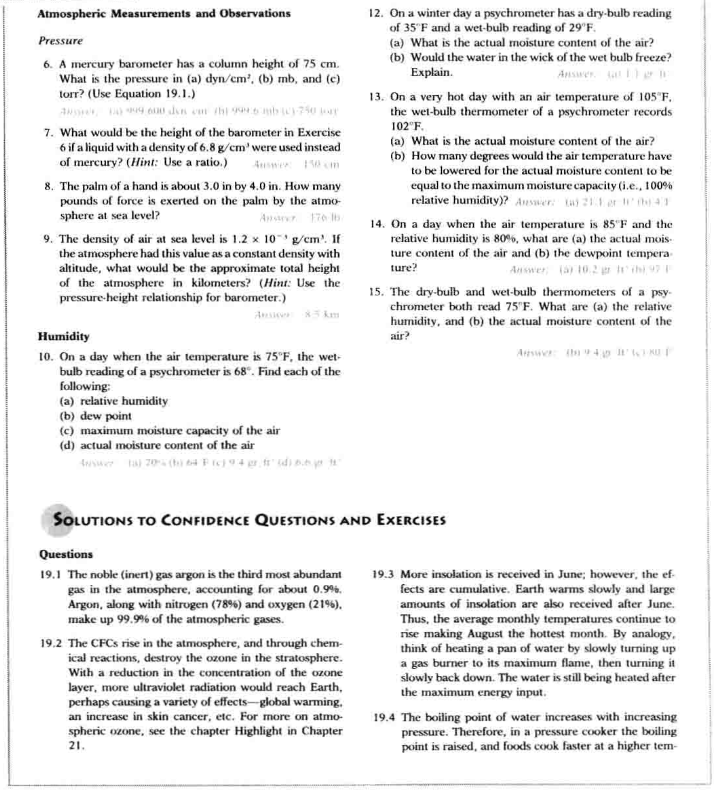
In the upper atmosphere the energetic particles from the Sun cause the ionization of the gas molecules. For example,

$$N_2 + \text{energy} \longrightarrow N_2^+ + e^-$$

The electrically charged ions and electrons are trapped in Earth's magnetic field and form ionic layers in the

Confidence Questions provide a self-check of the more conceptual or qualitative material.

Answers to Confidence Questions appear at the end of each chapter for immediate feedback to the student.



9 The Atmosphere

ıre (T) of the radiating source, show
gth of the light is inversely proportional
ıre—i.e., $\lambda \propto 1/T$.

Atmospheric Measurements and Observations

Pressure

6. A mercury barometer has a column height of 75 cm. What is the pressure in (a) dyn/cm², (b) mb, and (c) torr? (Use Equation 19.1.)
   Answer: (a) 999,600 dyn/cm² (b) 999.6 mb (c) 750 torr
7. What would be the height of the barometer in Exercise 6 if a liquid with a density of 6.8 g/cm³ were used instead of mercury? (*Hint:* Use a ratio.) *Answer:* 150 cm
8. The palm of a hand is about 3.0 in by 4.0 in. How many pounds of force is exerted on the palm by the atmosphere at sea level? *Answer:* 176 lb
9. The density of air at sea level is 1.2×10^{-3} g/cm³. If the atmosphere had this value as a constant density with altitude, what would be the approximate total height of the atmosphere in kilometers? (*Hint:* Use the pressure-height relationship for barometer.)
   Answer: 8.5 km

Humidity

10. On a day when the air temperature is 75°F, the wet-bulb reading of a psychrometer is 68°. Find each of the following:
    (a) relative humidity
    (b) dew point
    (c) maximum moisture capacity of the air
    (d) actual moisture content of the air
    Answer: (a) 70% (b) 64°F (c) 9.4 gr/ft³ (d) 6.6 gr/ft³
11. A psychrometer has a dry-bulb reading of 95°F and a wet-bulb reading of 90°F. Find each of the quantities asked for in Exercise 10.
12. On a winter day a psychrometer has a dry-bulb reading of 35°F and a wet-bulb reading of 29°F.
    (a) What is the actual moisture content of the air?
    (b) Would the water in the wick of the wet bulb freeze? Explain. *Answer:* (a) 1.1 gr/ft³
13. On a very hot day with an air temperature of 105°F, the wet-bulb thermometer of a psychrometer records 102°F.
    (a) What is the actual moisture content of the air?
    (b) How many degrees would the air temperature have to be lowered for the actual moisture content to be equal to the maximum moisture capacity (i.e., 100% relative humidity)? *Answer:* (a) 21.1 gr/ft³ (b) 4°F
14. On a day when the air temperature is 85°F and the relative humidity is 80%, what are (a) the actual moisture content of the air and (b) the dewpoint temperature? *Answer:* (a) 10.2 gr/ft³ (b) 97°F
15. The dry-bulb and wet-bulb thermometers of a psychrometer both read 75°F. What are (a) the relative humidity, and (b) the actual moisture content of the air?
    Answer: (b) 9.4 gr/ft³ (c) 80°F

SOLUTIONS TO CONFIDENCE QUESTIONS AND EXERCISES

Questions

19.1 The noble (inert) gas argon is the third most abundant gas in the atmosphere, accounting for about 0.9%. Argon, along with nitrogen (78%) and oxygen (21%), make up 99.9% of the atmospheric gases.

19.2 The CFCs rise in the atmosphere, and through chemical reactions, destroy the ozone in the stratosphere. With a reduction in the concentration of the ozone layer, more ultraviolet radiation would reach Earth, perhaps causing a variety of effects—global warming, an increase in skin cancer, etc. For more on atmospheric ozone, see the chapter Highlight in Chapter 21.

19.3 More insolation is received in June; however, the effects are cumulative. Earth warms slowly and large amounts of insolation are also received after June. Thus, the average monthly temperatures continue to rise making August the hottest month. By analogy, think of heating a pan of water by slowly turning up a gas burner to its maximum flame, then turning it slowly back down. The water is still being heated after the maximum energy input.

19.4 The boiling point of water increases with increasing pressure. Therefore, in a pressure cooker the boiling point is raised, and foods cook faster at a higher tem-

Important formulas are boxed in green for emphasis and quick identification. ⟶

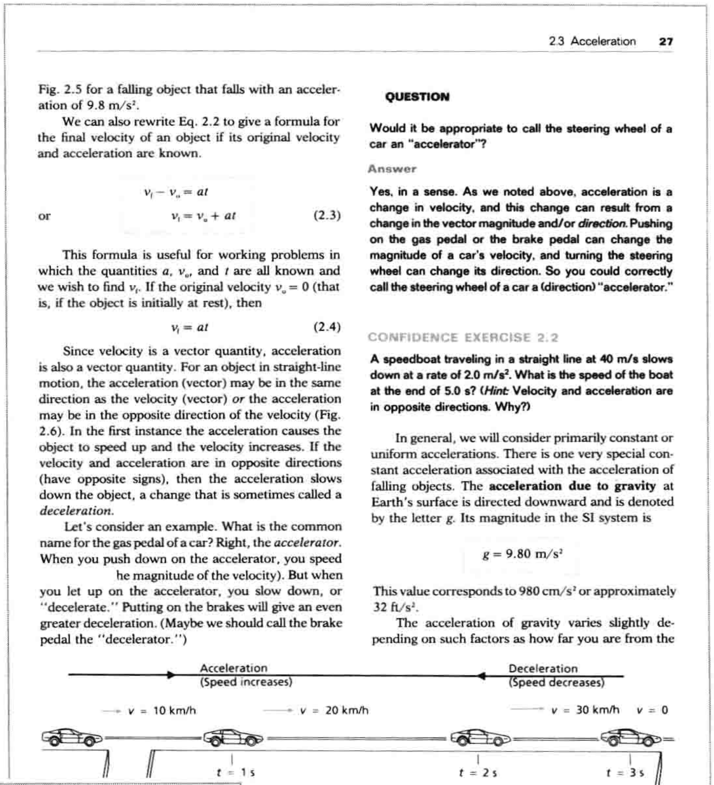


Fig. 2.5 for a falling object that falls with an acceleration of 9.8 m/s².

We can also rewrite Eq. 2.2 to give a formula for the final velocity of an object if its original velocity and acceleration are known.

$$v_f - v_o = at$$

or

$$v_f = v_o + at \qquad (2.3)$$

This formula is useful for working problems in which the quantities a, v_o, and t are all known and we wish to find v_f. If the original velocity $v_o = 0$ (that is, if the object is initially at rest), then

$$v_f = at \qquad (2.4)$$

Since velocity is a vector quantity, acceleration is also a vector quantity. For an object in straight-line motion, the acceleration (vector) may be in the same direction as the velocity (vector) *or* the acceleration may be in the opposite direction of the velocity (Fig. 2.6). In the first instance the acceleration causes the object to speed up and the velocity increases. If the velocity and acceleration are in opposite directions (have opposite signs), then the acceleration slows down the object, a change that is sometimes called a *deceleration.*

Let's consider an example. What is the common name for the gas pedal of a car? Right, the *accelerator.* When you push down on the accelerator, you speed he magnitude of the velocity). But when you let up on the accelerator, you slow down, or "decelerate." Putting on the brakes will give an even greater deceleration. (Maybe we should call the brake pedal the "decelerator.")

QUESTION

Would it be appropriate to call the steering wheel of a car an "accelerator"?

Answer

Yes, in a sense. As we noted above, acceleration is a change in velocity, and this change can result from a change in the vector magnitude and/or *direction*. Pushing on the gas pedal or the brake pedal can change the magnitude of a car's velocity, and turning the steering wheel can change its direction. So you could correctly call the steering wheel of a car a (direction) "accelerator."

CONFIDENCE EXERCISE 2.2

A speedboat traveling in a straight line at 40 m/s slows down at a rate of 2.0 m/s². What is the speed of the boat at the end of 5.0 s? (*Hint:* Velocity and acceleration are in opposite directions. Why?)

In general, we will consider primarily constant or uniform accelerations. There is one very special constant acceleration associated with the acceleration of falling objects. The **acceleration due to gravity** at Earth's surface is directed downward and is denoted by the letter g. Its magnitude in the SI system is

$$g = 9.80\ \mathrm{m/s^2}$$

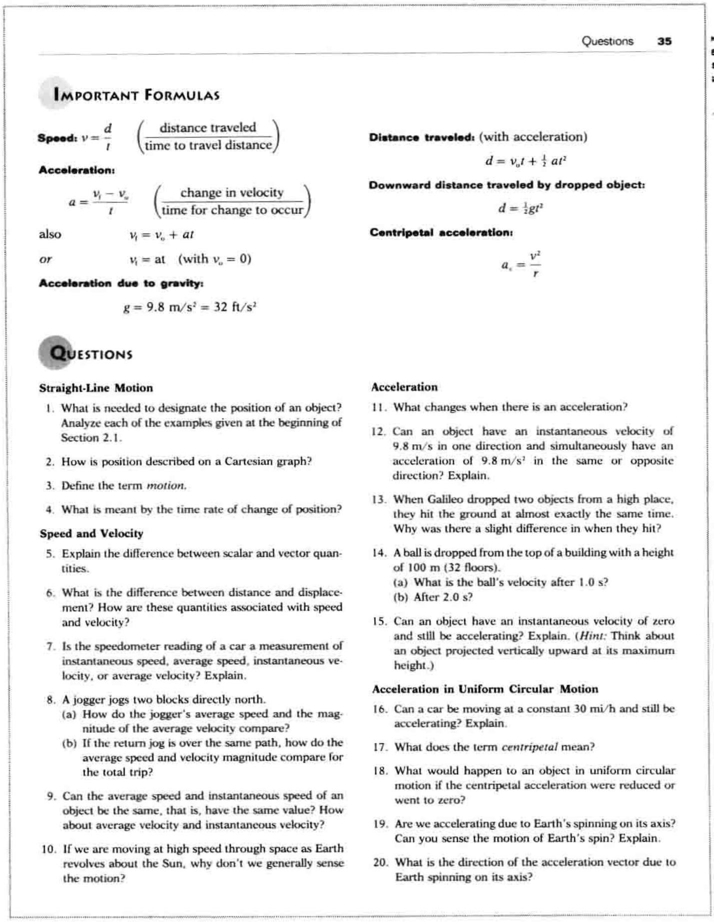
This value corresponds to 980 cm/s² or approximately 32 ft/s².

The acceleration of gravity varies slightly depending on such factors as how far you are from the

celeration.
ection as the velocity of an object in straight-line motion, s in the opposite direction of the velocity, then there is

Important formulas are listed conveniently for review at the end of each chapter.

↓



IMPORTANT FORMULAS

Speed: $v = \dfrac{d}{t}$ $\left(\dfrac{\text{distance traveled}}{\text{time to travel distance}}\right)$

Acceleration:

$$a = \frac{v_f - v_o}{t} \quad \left(\frac{\text{change in velocity}}{\text{time for change to occur}}\right)$$

also $v_f = v_o + at$

or $v_f = \mathrm{at}$ (with $v_o = 0$)

Acceleration due to gravity:

$$g = 9.8\ \mathrm{m/s^2} = 32\ \mathrm{ft/s^2}$$

Distance traveled: (with acceleration)

$$d = v_o t + \tfrac{1}{2}at^2$$

Downward distance traveled by dropped object:

$$d = \tfrac{1}{2}gt^2$$

Centripetal acceleration:

$$a_c = \frac{v^2}{r}$$

QUESTIONS

Straight-Line Motion

1. What is needed to designate the position of an object? Analyze each of the examples given at the beginning of Section 2.1.
2. How is position described on a Cartesian graph?
3. Define the term *motion.*
4. What is meant by the time rate of change of position?

Speed and Velocity

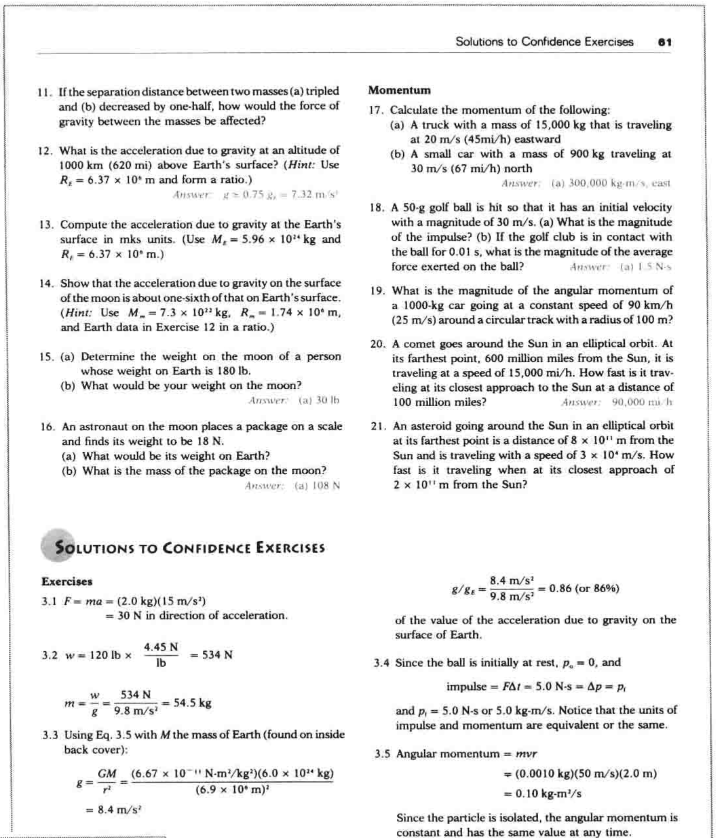
5. Explain the difference between scalar and vector quantities.
6. What is the difference between distance and displacement? How are these quantities associated with speed and velocity?
7. Is the speedometer reading of a car a measurement of instantaneous speed, average speed, instantaneous velocity, or average velocity? Explain.
8. A jogger jogs two blocks directly north.
   (a) How do the jogger's average speed and the magnitude of the average velocity compare?
   (b) If the return jog is over the same path, how do the average speed and velocity magnitude compare for the total trip?
9. Can the average speed and instantaneous speed of an object be the same, that is, have the same value? How about average velocity and instantaneous velocity?
10. If we are moving at high speed through space as Earth revolves about the Sun, why don't we generally sense the motion?

Acceleration

11. What changes when there is an acceleration?
12. Can an object have an instantaneous velocity of 9.8 m/s in one direction and simultaneously have an acceleration of 9.8 m/s² in the same or opposite direction? Explain.
13. When Galileo dropped two objects from a high place, they hit the ground at almost exactly the same time. Why was there a slight difference in when they hit?
14. A ball is dropped from the top of a building with a height of 100 m (32 floors).
   (a) What is the ball's velocity after 1.0 s?
   (b) After 2.0 s?
15. Can an object have an instantaneous velocity of zero and still be accelerating? Explain. (*Hint:* Think about an object projected vertically upward at its maximum height.)

Acceleration in Uniform Circular Motion

16. Can a car be moving at a constant 30 mi/h and still be accelerating? Explain.
17. What does the term *centripetal* mean?
18. What would happen to an object in uniform circular motion if the centripetal acceleration were reduced or went to zero?
19. Are we accelerating due to Earth's spinning on its axis? Can you sense the motion of Earth's spin? Explain.
20. What is the direction of the acceleration vector due to Earth spinning on its axis?



Solutions to Confidence Exercises **61**

11. If the separation distance between two masses (a) tripled and (b) decreased by one-half, how would the force of gravity between the masses be affected?

12. What is the acceleration due to gravity at an altitude of 1000 km (620 mi) above Earth's surface? (*Hint:* Use $R_E = 6.37 \times 10^6$ m and form a ratio.)
Answer: $g \approx 0.75\, g_E = 7.32$ m/s²

13. Compute the acceleration due to gravity at the Earth's surface in mks units. (Use $M_E = 5.96 \times 10^{24}$ kg and $R_E = 6.37 \times 10^6$ m.)

14. Show that the acceleration due to gravity on the surface of the moon is about one-sixth of that on Earth's surface. (*Hint:* Use $M_m = 7.3 \times 10^{22}$ kg, $R_m = 1.74 \times 10^6$ m, and Earth data in Exercise 12 in a ratio.)

15. (a) Determine the weight on the moon of a person whose weight on Earth is 180 lb.
    (b) What would be your weight on the moon?
Answer: (a) 30 lb

16. An astronaut on the moon places a package on a scale and finds its weight to be 18 N.
    (a) What would be its weight on Earth?
    (b) What is the mass of the package on the moon?
Answer: (a) 108 N

Momentum

17. Calculate the momentum of the following:
    (a) A truck with a mass of 15,000 kg that is traveling at 20 m/s (45mi/h) eastward
    (b) A small car with a mass of 900 kg traveling at 30 m/s (67 mi/h) north
Answer: (a) 300,000 kg-m/s, east

18. A 50-g golf ball is hit so that it has an initial velocity with a magnitude of 30 m/s. (a) What is the magnitude of the impulse? (b) If the golf club is in contact with the ball for 0.01 s, what is the magnitude of the average force exerted on the ball? *Answer:* (a) 1.5 N-s

19. What is the magnitude of the angular momentum of a 1000-kg car going at a constant speed of 90 km/h (25 m/s) around a circular track with a radius of 100 m?

20. A comet goes around the Sun in an elliptical orbit. At its farthest point, 600 million miles from the Sun, it is traveling at a speed of 15,000 mi/h. How fast is it traveling at its closest approach to the Sun at a distance of 100 million miles? *Answer:* 90,000 mi/h

21. An asteroid going around the Sun in an elliptical orbit at its farthest point is a distance of 8×10^{11} m from the Sun and is traveling with a speed of 3×10^4 m/s. How fast is it traveling when at its closest approach of 2×10^{11} m from the Sun?

SOLUTIONS TO CONFIDENCE EXERCISES

Exercises

3.1 $F = ma = (2.0\text{ kg})(15\text{ m/s}^2)$
$= 30$ N in direction of acceleration.

3.2 $w = 120\text{ lb} \times \dfrac{4.45\text{ N}}{\text{lb}} = 534\text{ N}$

$$m = \frac{w}{g} = \frac{534\text{ N}}{9.8\text{ m/s}^2} = 54.5\text{ kg}$$

3.3 Using Eq. 3.5 with *M* the mass of Earth (found on inside back cover):

$$g = \frac{GM}{r^2} = \frac{(6.67 \times 10^{-11}\text{ N-m}^2/\text{kg}^2)(6.0 \times 10^{24}\text{ kg})}{(6.9 \times 10^6\text{ m})^2}$$
$$= 8.4\text{ m/s}^2$$

$$g/g_E = \frac{8.4\text{ m/s}^2}{9.8\text{ m/s}^2} = 0.86\text{ (or 86\%)}$$

of the value of the acceleration due to gravity on the surface of Earth.

3.4 Since the ball is initially at rest, $p_o = 0$, and

$$\text{impulse} = F\Delta t = 5.0\text{ N-s} = \Delta p = p_f$$

and $p_f = 5.0$ N-s or 5.0 kg-m/s. Notice that the units of impulse and momentum are equivalent or the same.

3.5 Angular momentum $= mvr$
$= (0.0010\text{ kg})(50\text{ m/s})(2.0\text{ m})$
$= 0.10\text{ kg-m}^2/\text{s}$

Since the particle is isolated, the angular momentum is constant and has the same value at any time.

Solutions to Confidence Exercises appear at the end of each chapter for convenient reference. →

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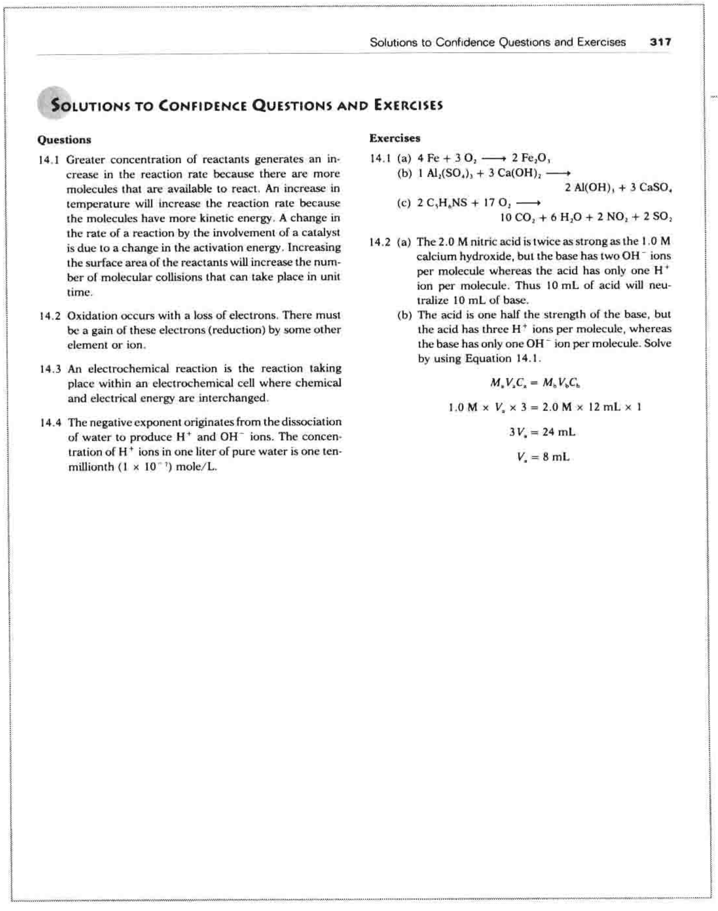

Solutions to Confidence Questions and Exercises **317**

SOLUTIONS TO CONFIDENCE QUESTIONS AND EXERCISES

Questions

14.1 Greater concentration of reactants generates an increase in the reaction rate because there are more molecules that are available to react. An increase in temperature will increase the reaction rate because the molecules have more kinetic energy. A change in the rate of a reaction by the involvement of a catalyst is due to a change in the activation energy. Increasing the surface area of the reactants will increase the number of molecular collisions that can take place in unit time.

14.2 Oxidation occurs with a loss of electrons. There must be a gain of these electrons (reduction) by some other element or ion.

14.3 An electrochemical reaction is the reaction taking place within an electrochemical cell where chemical and electrical energy are interchanged.

14.4 The negative exponent originates from the dissociation of water to produce H^+ and OH^- ions. The concentration of H^+ ions in one liter of pure water is one ten-millionth (1×10^{-7}) mole/L.

Exercises

14.1 (a) $4\,Fe + 3\,O_2 \longrightarrow 2\,Fe_2O_3$
(b) $1\,Al_2(SO_4)_3 + 3\,Ca(OH)_2 \longrightarrow 2\,Al(OH)_3 + 3\,CaSO_4$
(c) $2\,C_5H_6NS + 17\,O_2 \longrightarrow 10\,CO_2 + 6\,H_2O + 2\,NO_2 + 2\,SO_2$

14.2 (a) The 2.0 M nitric acid is twice as strong as the 1.0 M calcium hydroxide, but the base has two OH^- ions per molecule whereas the acid has only one H^+ ion per molecule. Thus 10 mL of acid will neutralize 10 mL of base.
(b) The acid is one half the strength of the base, but the acid has three H^+ ions per molecule, whereas the base has only one OH^- ion per molecule. Solve by using Equation 14.1.

$$M_aV_aC_a = M_bV_bC_b$$
$$1.0\text{ M} \times V_a \times 3 = 2.0\text{ M} \times 12\text{ mL} \times 1$$
$$3V_a = 24\text{ mL}$$
$$V_a = 8\text{ mL}$$

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APPENDIXES

Fundamentals of Physical Science