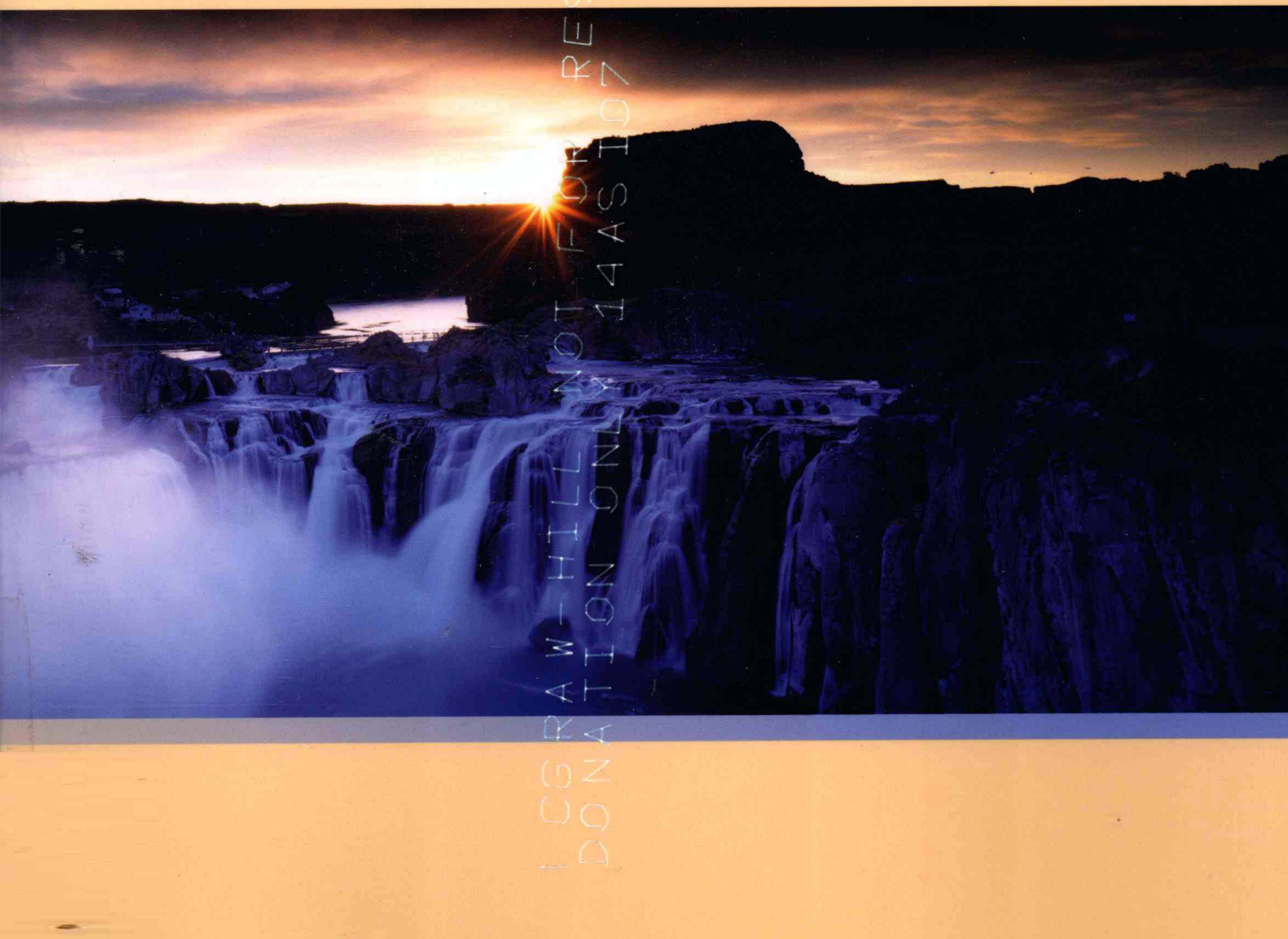
THE Physical Universe

ELEVENTH EDITION



KONRAD B. KRAUSKOPF

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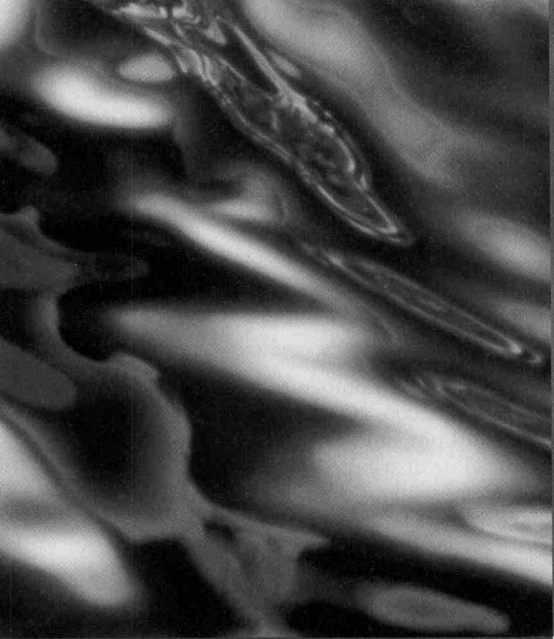

The Physical Universe

Eleventh Edition

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Arthur Beiser

McGraw-Hill Higher Education

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THE PHYSICAL UNIVERSE, ELEVENTH EDITION

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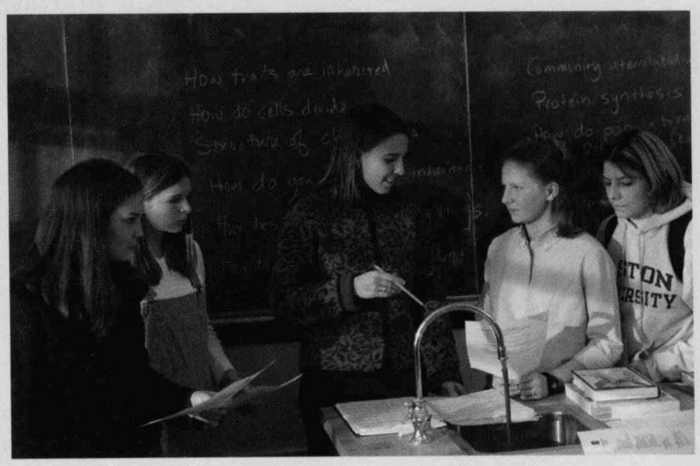
Preface

Creating Informed Citizens

The aim of *The Physical Universe* is to present, as simply and clearly as possible, the essentials of physics, chemistry, earth science, and astronomy to students whose main interests lie elsewhere.

Because of the scope of these sciences and because we assume minimal preparation on the part of the reader, our choice of topics and how far to develop them had to be limited. The emphasis throughout is on the basic concepts of each discipline. We also try to show how scientists approach problems and why science is a never-ending quest rather than a fixed set of facts. The book concentrates on those aspects of the physical sciences most relevant to a nonscientist who wants to understand how the universe works and to know something about the connections between science and everyday life. We hope to equip readers to appreciate major developments in science as they arrive and to be able to act as informed citizens on matters that involve science and public policy.



Two features of the book emphasize the human element. One is a series of biographies of important contributors to the physical sciences from Archimedes to today. The other consists of essays by distinguished young scientists—Timothy C. Miller (a physicist), Cynthia M. Friend (a chemist), Andrea Donnellan (a geophysicist), and Wendy Freedman (an astronomer)—which give an idea of what a typical day at work involves for each of them and nicely conveys the excitement of being at the frontier of knowledge.

> *"This is a well-written book. The authors cover the key topics at a level that is effective for the proposed audience. There are lots of figures that assist the written presentation. The end-of-chapter problems are excellent in that many of them ask the student to apply material rather than recite it. The many biographies put a face on science. The book earns a grade of A."*
>
> —Peter Hamlet, *Pittsburg State University*

Scope and Organization

There are many possible ways to organize a book of this kind. We chose the one that provides the most logical progression of ideas, so that each new subject builds on the ones that came before.

> *"One strength is its organizational style—beginning with physics, moving to chemistry, and then applying this knowledge to the weather, geology, and astronomy. The first chapter is a particular*

strength—discussing the nature of science and science as a process with some examples. Finally, I believe that the book is generally well laid out in its visual appearance: the figures do a good job of supplementing the text."

—Jennifer J. Birriel, *Morehead State University*

Our first concern in *The Physical Universe* is the scientific method, using as illustration the steps that led to today's picture of the universe and the earth's place in it. Next we consider motion and the influences that affect moving bodies. Gravity, energy, and momentum are examined, and the theory of relativity is introduced. Matter in its three states next draws our attention, and we pursue this theme from the kinetic-molecular model to the laws of thermodynamics and the significance of entropy. A grounding in electricity and magnetism follows, and then an exploration of wave phenomena that includes the electromagnetic theory of light. We go on from there to the atomic nucleus and elementary particles, followed by a discussion of the quantum theories of light and of matter that lead to the modern view of atomic structure.

"The strongest feature of the text is its introduction. The first chapter establishes a pertinent theme that unifies the text. The authors do an excellent job of defining the scientific method and using the historical development of how the "heavens" are viewed to exemplify their approach. There are also many examples where the ideas introduced in chapter one are reinforced in subsequent chapters. Artificial satellites, rockets, the fate of the universe, and the Doppler effect all build on the initial ideas and themes."

—Capp Yess, *Morehead State University*

"This is exactly what I teach! . . . very well written. I liked the way the relation between distance, velocity, and time are shown . . . the way Newton's Laws are presented. The discussion on "Why Satellites Don't Fall Down" is nicely written for the students."

—Kingshuk Majumdar, *Berea College*

The transition from physics to chemistry is made via the periodic table. A look at chemical bonds and how they act to hold together molecules, solids, and liquids is followed by a survey of chemical reactions, organic chemistry, and the chemistry of life.

"In my 36 years of teaching chemistry and physics, I have discovered that spending a quality and quantity of time on the Periodic Law and the Periodic Table can prove very interesting to students and can open up many areas of understanding of chemistry topics which naturally follow. This chapter [chapter 9] does an EXCELLENT job of introducing and elaborating on the logical organization of the Table and how essential it is to a basic understanding of the many phases and combinations of matter."

—William M. Scott, *Fort Hays State University*

Our concern now shifts to the planet on which we live, and we begin by inquiring into the oceans of air and water that cover it. From there we proceed to the materials of the earth, to its ever-evolving crust, and to its no-longer-mysterious interior. After a brief narrative of the earth's geological history we go on to what we know about our nearest neighbors in space—planets and satellites, asteroids, meteoroids, and comets.

Now the sun, the monarch of the solar system and the provider of nearly all our energy, claims our notice. We go on to broaden our astronomical sights to include the other stars, both individually and as members of the immense assemblies called galaxies. The evolution of the universe starting from the big bang is the last major subject, and we end with the origin of the earth and the likelihood that other inhabited planets exist in the universe and how we might communicate with them.

> *"With the various spacecraft in the last couple of decades, the Hubble Space Telescope, and the ongoing study of lunar samples and meteorites, there is an immense amount of information that is available for inclusion in a chapter [chapter 16] such as this. The authors have done an excellent job of deciding what to include, and the result is an excellent overview chapter that is as current as it can be in this rapidly growing subject."*
>
> —Eric Jerde, *Morehead State University*

> *"This is one of the best chapters [chapter 17] on stars in a text of this level that I have read. It addresses the various aspects of the stars (size, distance, evolution, etc.) in an easy to understand manner. It also provides information concerning the history of the current knowledge of stars."*
>
> —Wilda Pounds, *Northeast Mississippi Community College*

Mathematical Level

The physical sciences are quantitative, which has both advantages and disadvantages. On the plus side, the use of mathematics means that every concept must be in the form of a clear, definite statement whose predictions can be tested objectively. Less welcome is the discomfort many of us feel when faced with mathematical reasoning and calculations. To minimize such discomfort, previous editions of *The Physical Universe* used mathematical arguments sparingly, which meant that an important part of the story of how physics and chemistry work to make sense of the natural world and how their findings led to the technological world of today could only be hinted at.

At the request of many teachers who feel their students are able and willing to go further, the book now uses mathematics a little more freely than before. As a result, it is no longer necessary to pull the kinetic energy formula $\frac{1}{2}mv^2$ out of a hat, for instance, and how the mole connects chemical ideas with the real world can be explored. Nevertheless, the mathematical level remains modest, and the new material, which supplements rather than dominates the presentation, does not have to be mastered to understand the rest of the book. The basic algebra needed is reviewed in the Math Refresher. Powers-of-ten notation for small and large numbers is carefully explained there. This section is selfcontained and can provide all the math background needed.

New To This Edition

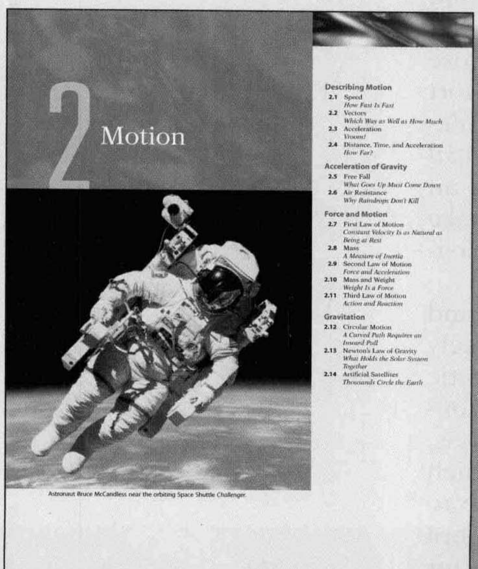
Because the organization of the previous edition worked well in the classroom, it was not changed. In addition to the somewhat greater use of mathematics mentioned above, the changes for this edition came under four headings.

New Topics The coverage was expanded by adding a variety of new material, for example on accelerated motion, specific heat capacity, pressure in a fluid, the nature of charge, index of refraction, ray tracing, the periodic table, colloids, quantitative chemistry, dew point, Portland cement, mass extinctions, gamma-ray bursts, and dark energy.

Updating Recent findings and their interpretations were incorporated where appropriate. The sections dealing with energy generation and use, the solar system, and the evolution of the universe received particular attention.

Illustrations The illustrations, both line drawings and photographs, are full partners to the text and provide a visual pathway to understanding scientific observations and principles for students unaccustomed to abstract argument. Thirty-eight new illustrations are included in this edition.

Exercises A number of exercises of each kind were replaced and many new ones added to give a total of 1686, an average of over ninety per chapter.


2 Motion

Describing Motion
2.1 Speed *How Fast Is Fast*
2.2 Vectors *Which Way as Well as How Much*
2.3 Acceleration *Vroom!*
2.4 Distance, Time, and Acceleration *How Far?*

Acceleration of Gravity
2.5 Free Fall *What Goes Up Must Come Down*
2.6 Air Resistance *Why Raindrops Don't Kill*

Force and Motion
2.7 First Law of Motion *Constant Velocity Is as Natural as Being at Rest*
2.8 Mass *A Measure of Inertia*
2.9 Second Law of Motion *Force and Acceleration*
2.10 Mass and Weight *Weight Is a Force*
2.11 Third Law of Motion *Action and Reaction*

Gravitation
2.12 Circular Motion *A Curved Path Requires an Inward Pull*
2.13 Newton's Law of Gravity *What Holds the Solar System Together*
2.14 Artificial Satellites *Thousands Circle the Earth*

Astronaut Bruce McCandless near the orbiting Space Shuttle *Challenger*.

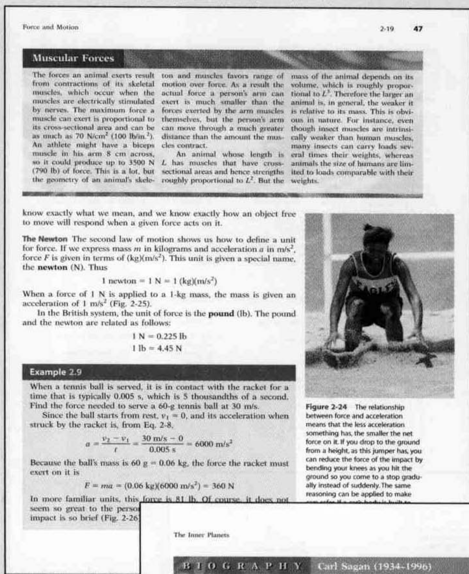
The Learning System

A variety of aids are provided in *The Physical Universe* to help the reader master the text.

Chapter Outline A preview of major topics is included on the opening page of each chapter, showing at a glance what the chapter covers.

Bringing Science to Life

Worked Examples A full grasp of physical and chemical ideas includes an ability to solve problems based on these ideas. Some students, although able to follow the discussions in the book, nevertheless may have trouble putting their knowledge to use in this way. To help them, detailed solutions of typical problems are provided that show how to apply formulas and equations to real-world situations. Besides the worked examples, outline solutions for half the end-of-chapter problems are given at the end of the text, for a total of nearly 200 model solutions. Thinking through these solutions should bring the unsolved even-numbered problems within reach. Besides its role in reinforcing the understanding of physical and chemical ideas, solving problems can provide great pleasure, and it would be a shame to miss out on this pleasure.


Force and Motion 2-19 47

Muscular Forces

The forces an animal exerts result from contractions of its skeletal muscles, which occur when the muscles are electrically stimulated by nerves. The maximum force a muscle can exert is proportional to its cross-sectional area and can be as much as 70 N/cm² (100 lb/in.²). An athlete might have a biceps muscle in his arm 8 cm across, so it could produce up to 3500 N (790 lb) of force. This is a lot, but the geometry of an animal's skeleton and muscles favors range of motion over force. As a result the actual force a person's arm can exert is much smaller than the forces exerted by the arm muscles themselves, but the person's arm can move through a much greater distance than the amount the muscles contract.

An animal whose length is L has muscles that have cross-sectional areas and hence strengths roughly proportional to L^2. But the mass of the animal depends on its volume, which is roughly proportional to L^3. Therefore the larger an animal is, in general, the weaker it is relative to its mass. This is obvious in nature. For instance, even though insect muscles are intrinsically weaker than human muscles, many insects can carry loads several times their weights, whereas animals the size of humans are limited to loads comparable with their weights.

know exactly what we mean, and we know exactly how an object free to move will respond when a given force acts on it.

The Newton The second law of motion shows us how to define a unit for force. If we express mass m in kilograms and acceleration a in m/s², force F is given in terms of (kg)(m/s²). This unit is given a special name, the **newton** (N). Thus

$$1 \text{ newton} = 1 \text{ N} = 1 \text{ (kg)(m/s}^2)$$

When a force of 1 N is applied to a 1-kg mass, the mass is given an acceleration of 1 m/s² (Fig. 2-25).

In the British system, the unit of force is the **pound** (lb). The pound and the newton are related as follows:

$$1 \text{ N} = 0.225 \text{ lb}$$
$$1 \text{ lb} = 4.45 \text{ N}$$

Example 2.9

When a tennis ball is served, it is in contact with the racket for a time that is typically 0.005 s, which is 5 thousandths of a second. Find the force needed to serve a 60-g tennis ball at 30 m/s.

Since the ball starts from rest, $v_1 = 0$, and its acceleration when struck by the racket is, from Eq. 2-8,

$$a = \frac{v_2 - v_1}{t} = \frac{30 \text{ m/s} - 0}{0.005 \text{ s}} = 6000 \text{ m/s}^2$$

Because the ball's mass is 60 g = 0.06 kg, the force the racket must exert on it is

$$F = ma = (0.06 \text{ kg})(6000 \text{ m/s}^2) = 360 \text{ N}$$

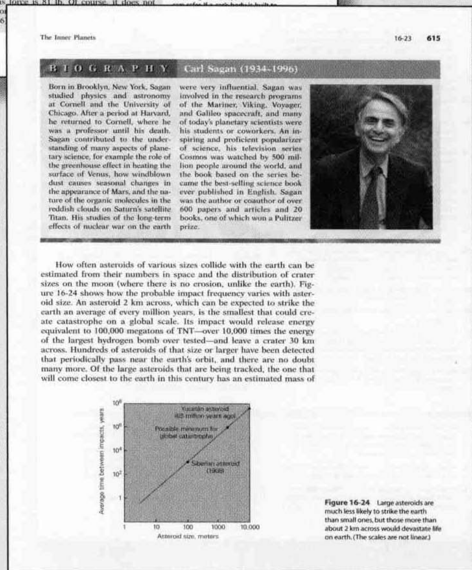
In more familiar units, this force is 81 lb. Of course, it does not seem so great to the perso... impact is so brief (Fig. 2-26...

Figure 2-24 The relationship between force and acceleration means that the less acceleration something has, the smaller the net force on it. If you drop to the ground from a height, as this jumper has, you can reduce the force of the impact by bending your knees as you hit the ground so you come to a stop gradually instead of suddenly. The same reasoning can be applied to make

"The examples in text are good, well illustrated and use unit analysis effectively. The examples are routinely followed at the end of the chapter with similar problems."

—Capp Yess, *Morehead State University*

Biographies Brief biographies of 40 major figures in the development of the physical sciences appear where appropriate throughout the text. The biographies provide human and historical perspectives by attaching faces and stories to milestones in these sciences.


The Inner Planets 16-23 615

BIOGRAPHY Carl Sagan (1934–1996)

Born in Brooklyn, New York, Sagan studied physics and astronomy at Cornell and the University of Chicago. After a period at Harvard, he returned to Cornell, where he was a professor until his death. Sagan contributed to the understanding of many aspects of planetary science, for example the role of the greenhouse effect in heating the surface of Venus, how windblown dust causes seasonal changes in the appearance of Mars, and the nature of the organic molecules in the reddish clouds on Saturn's satellite Titan. His studies of the long-term effects of nuclear war on the earth were very influential. Sagan was involved in the research programs of the Mariner, Viking, Voyager, and Galileo spacecraft, and many of today's planetary scientists were his students or coworkers. An inspiring and proficient popularizer of science, his television series Cosmos was watched by 500 million people around the world, and the book based on the series became the best-selling science book ever published in English. Sagan was the author or coauthor of over 600 papers and articles and 20 books, one of which won a Pulitzer prize.

How often asteroids of various sizes collide with the earth can be estimated from their numbers in space and the distribution of crater sizes on the moon (where there is no erosion, unlike the earth). Figure 16-24 shows how the probable impact frequency varies with asteroid size. An asteroid 2 km across, which can be expected to strike the earth an average of every million years, is the smallest that could create catastrophe on a global scale. Its impact would release energy equivalent to 100,000 megatons of TNT—over 10,000 times the energy of the largest hydrogen bomb over tested—and leave a crater 30 km across. Hundreds of asteroids of that size or larger have been detected that periodically pass near the earth's orbit, and there are no doubt many more. Of the large asteroids that are being tracked, the one that will come closest to the earth in this century has an estimated mass of

Figure 16-24 Large asteroids are much less likely to strike the earth than small ones, but those more than about 2 km across would devastate life on earth. (The scales are not linear.)

"I like the biographies and information boxes that are appropriately placed throughout the chapters. It provides a connection between the material the students are learning and the people that helped to bring that information to them."

—Timothy T. Ehler, *Buena Vista University*

Sidebars These are brief accounts of topics related to the main text. A sidebar may provide additional information on a particular subject, comment on its significance, describe its applications, consider its historical background, or present recent findings.

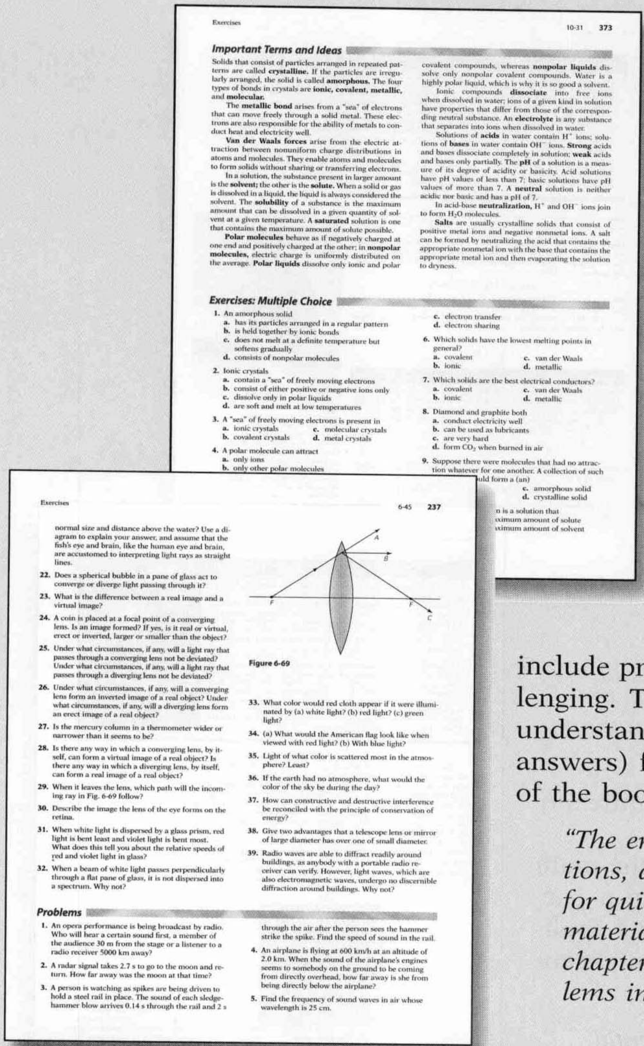
"In the physics section, in which most of the fundamental principles were discovered decades ago, the coverage still is current because the authors use examples from current topics. . . . The examples and sidebar topics are from very current research. Examples include the discussions of maglev trains, wind energy and solar cells, gravitational waves etc."

—Kent J. Price, *Morehead State University*

At Work Essays Four young scientists who have carried out important research in their respective fields have contributed accounts of how their days at work are spent. The enthusiasm and dedication they bring to their probes of the physical universe show clearly in these essays.

End of Chapter Features

Important Terms and Ideas Important terms introduced in the chapter are listed together with their meanings, which serves as a chapter summary. A list of the **Important Formulas** needed to solve problems based on the chapter material is also given where appropriate.



"The 'key ideas' discussion is a great idea, particularly with 'bold' words for those words that may be unfamiliar to some students."

—T.D. Sauncy, *Angelo State University*

There are a variety of exercises, questions, and problems on all levels of difficulty following each chapter. They are of three kinds:

Multiple-Choice Exercises An average chapter has 38 multiple-choice exercises (with answers) that act as a quick, painless check on understanding. Correct answers provide reinforcement and encouragement; incorrect ones identify areas of weakness.

Questions Some of the questions are meant to find out how well the reader has understood the chapter material. Others ask the reader to apply what he or she has learned to new situations. Answers to the odd-numbered questions are given at the back of the book.

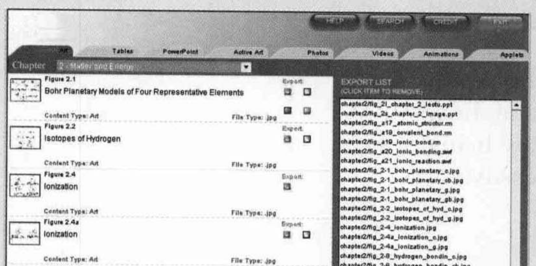
Problems The physics and chemistry chapters include problems that range from quite easy to moderately challenging. The ability to work out such problems signifies a real understanding of these subjects. Outline solutions (not just answers) for the odd-numbered problems are given at the back of the book.

"The end of chapter material is very useful. Exercises, questions, and problems are comprehensive—there are exercises for quick review, questions to spur deeper thought about the material, and problems to test student ability to apply the chapter material. Having outlines of the odd-numbered problems instead of answers only is very helpful to the students.

—Kent J. Price, *Morehead State University*

Additional Resources for *The Physical Universe*

Digital Content Manager

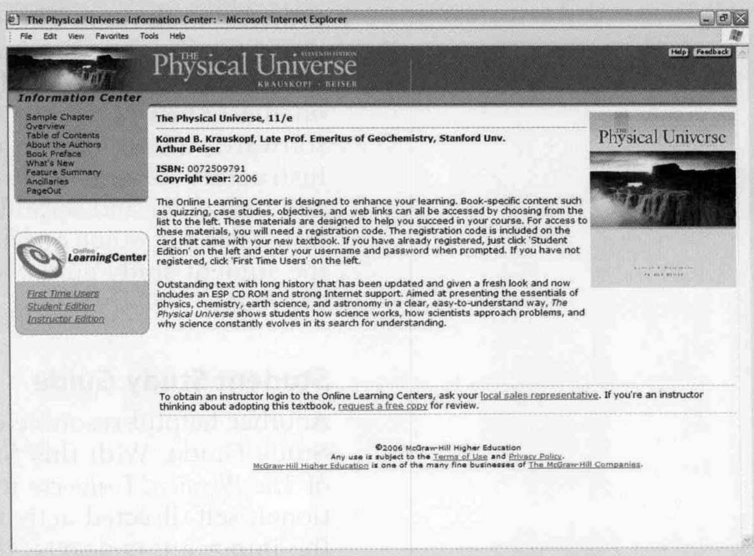


The **Digital Content Manager** contains jpeg files of the four-color images, tables, and worked examples from the text as well as a selection of animations and PowerPoints of the text images and sample lectures. These digital assets are contained on a cross-platform CD-ROM and are grouped by chapter within a user-friendly interface. With the help of these valuable resources, instructors can create customized classroom presentations, visually based tests and quizzes, dynamic course website content, and attractive printed support materials.

"Obviously, much work has been put into producing a book that will keep the interest of students. The illustrations, charts, and photos are timely and well done.

—Wilda Pounds, *Northeast Mississippi Community College*

Online Learning Center

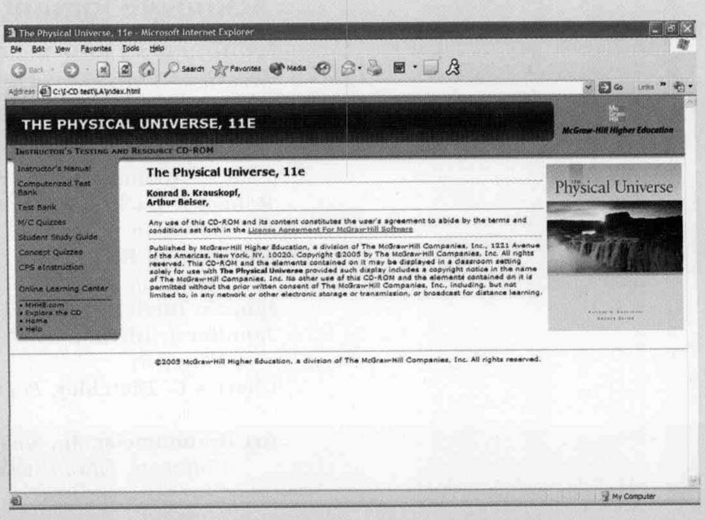


McGraw-Hill's Online Learning Center for *The Physical Universe* is a complete online self-study and course resource system. The Online Learning Center is customized to Krauskopf and Beiser's *The Physical Universe* textbook. Instructors have access to the fully downloadable instructor's manual. The instructor's manual, written by the text authors, provides answers and solutions to the even-numbered end-of-chapter questions and problems not provided in the text. The Online Learning Center also contains the figures from the text in jpeg format; text-specific questions in CPS eInstruction format; daily concept quizzes for just-in-time teaching techniques; sample PowerPoint lectures; animations; links to resources; clip art; and many other features.

Students can use the Online Learning Center to study in a variety of ways. Many learning aids to test understanding of chapter concepts are available, such as, self-quizzes in multiple-choice and matching formats with online feedback. Other items correlated to the main text include chapter goals, outlines, and weblinks. The Online Learning Center also includes a collection of animations to help students visualize concepts and up-to-the minute news feeds on current physical science topics.

CPS eInstruction

The Classroom Performance System (CPS) brings interactivity into the classroom or lecture hall. It is a wireless response system that gives the instructor and students immediate feedback from the entire class. The wireless response pads are essentially remotes that are easy to use and engage students. CPS allows instructors to motivate student preparation, interactivity, and active learning. Instructors receive immediate feedback to assess which concepts students understand. Questions covering the content of the *Physical Universe* text and formatted in the CPS eInstruction software are available on the *Physical Universe* Online Learning Center.



Instructor's Testing and Resource CD-ROM

The cross-platform CD-ROM contains the Instructor's Manual and Test Bank, available in both Word and PDF formats. The instructor's manual, written by the text authors, provides answers and solutions to the even-numbered end-of-chapter questions and problems not provided in the text. The Test Bank of over 900 additional questions and problems can be used for homework assignments and/or the preparation of exams. These additional Test Bank questions are also included on the CD-ROM within a computerized test bank. This user-friendly software can be used to quickly create customized exams by allowing instructors to sort questions by format; edit existing questions or add new ones; and scramble questions for multiple versions of the same test. Files for other questions from the online learning center quizzes, the student study guide, and CPS eInstruction are also provided on the CD-ROM.

Student Study Guide

Another helpful resource can be found in *The Physical Universe* Student Study Guide. With this Study Guide, students will maximize their use of *The Physical Universe* text package. It supplements the text with additional, self-directed activities and complements the text by focusing on the important concepts, theories, facts, and processes presented by the authors.

Overhead Transparencies

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

Primis Online

This text can be customized in print or in an electronic format to meet exact course needs. McGraw-Hill's Primis Online allows instructors to select desired chapters and preferred sequence and to choose supplements from the many science items on our database. Visit **http://www.primiscontentcenter.com/** to begin today.

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Nancy Woods of Des Moines Area Community College compiled the Videolists in the *Instructor's Manual/Test Bank for The Physical Universe.*

It is with great sadness that I have to report the death of Konrad B. Krauskopf on May 8, 2003. We worked together for 45 years on this and other books, and I will miss his wise counsel.

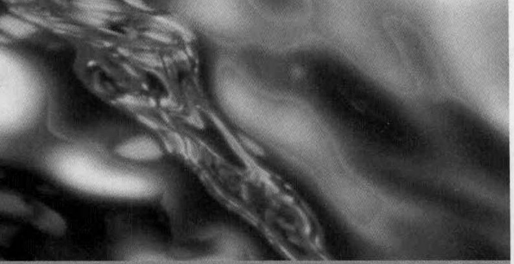
Finally, I want to thank my friends at McGraw-Hill for their skilled and dedicated help in producing this edition.

Arthur Beiser

Meet the Authors

Konrad B. Krauskopf was born and raised in Madison, Wisconsin and earned a B.S. in chemistry from University of Wisconsin in 1931. He then earned a Ph.D. in chemistry at the University of California in Berkeley. When the Great Depression made jobs in chemistry scarce, Professor Krauskopf decided to study geology, which had long fascinated him. Through additional graduate work at Stanford University, he earned a second Ph.D. and eventually a position on the Stanford faculty. He remained at Stanford until his retirement in 1976. During his tenure, Professor Krauskopf also worked at various times with the U.S. Geological Survey, served with the U.S. army in occupied Japan, and traveled to Norway, France, and Germany on sabbatical leaves. His research interests include field work on granites and metamorphic rocks and laboratory study on applications of chemistry to geologic problems, especially the formation of ore deposits. In recent years, Professor Krauskopf has spent time working with various government agencies on the problem of radioactive waste disposal.

Arthur Beiser, a native of New York City, received B.S., M.S., and Ph.D. degrees in physics from New York University, where he later served as Associate Professor of Physics. He then was Senior Research Scientist at the Lamont Geological Observatory of Columbia University. His research interests were chiefly in cosmic rays and magnetohydrodynamics as applied to geophysics and astrophysics. In addition to theoretical work, he participated in a cosmic-ray expedition to an Alaskan peak and directed a search for magnetohydrodynamic waves from space in various Pacific locations. He is the author or coauthor of 36 books, mostly college texts on physics and mathematics, 14 of which have been translated into a total of 21 languages. Two of his books are on sailing, *The Proper Yacht* and *The Sailor's World.* Figure 12-18 is a photograph of Dr. Beiser at the helm of his 58-ft sloop.



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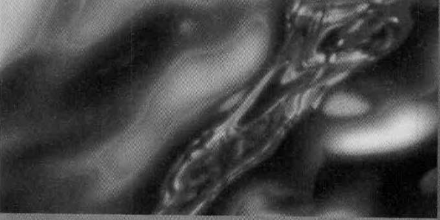

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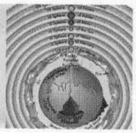

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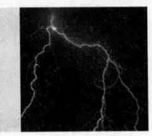

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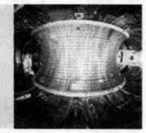

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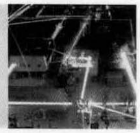

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