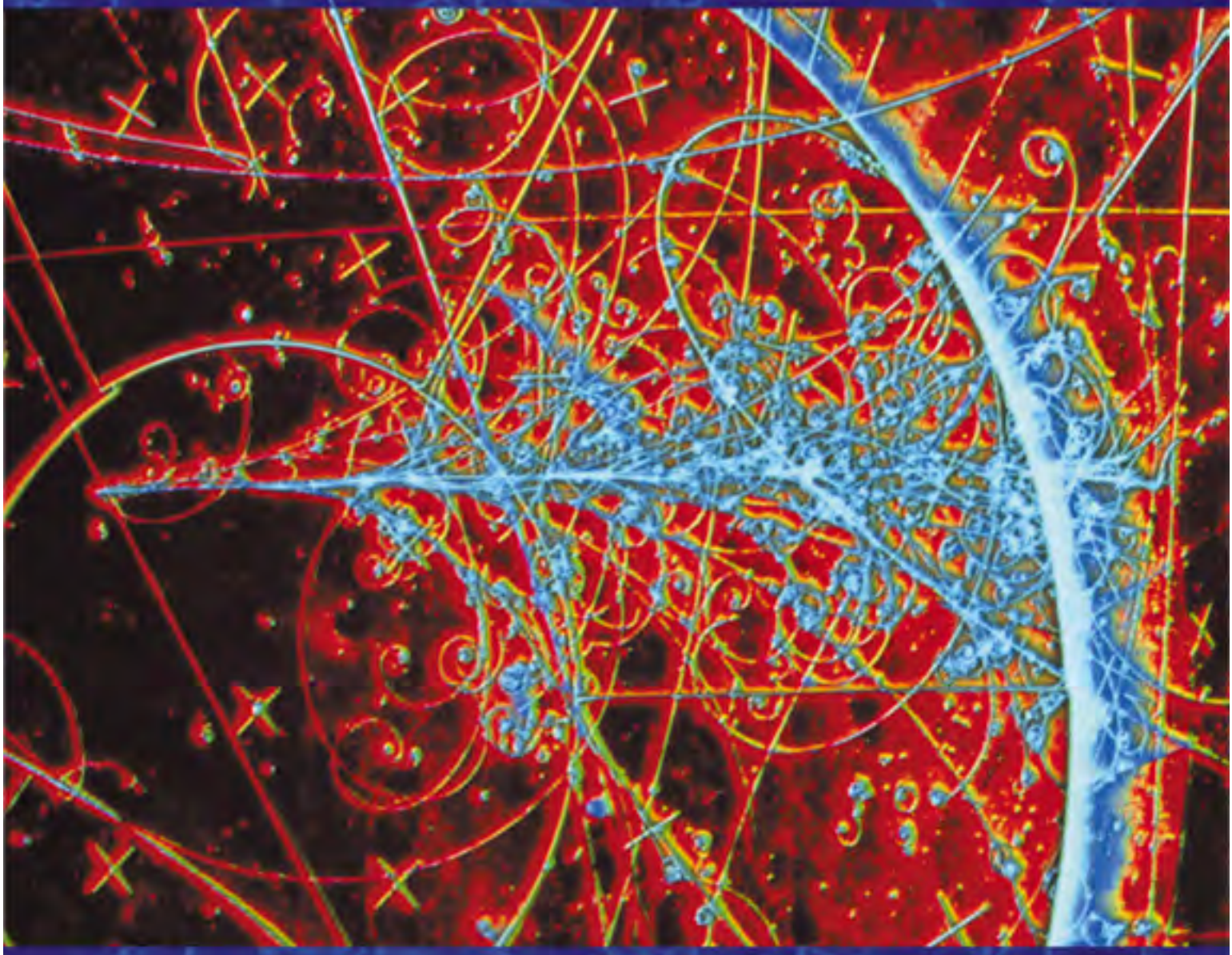
third edition

MODERN PHYSICS



SERWAY / MOSES / MOYER

Preface

This book is intended as a modern physics text for science majors and engineering students who have already completed an introductory calculus-based physics course. The contents of this text may be subdivided into two broad categories: an introduction to the theories of relativity, quantum and statistical physics (Chapters 1 through 10) and applications of elementary quantum theory to molecular, solid-state, nuclear, and particle physics (Chapters 11 through 16).

OBJECTIVES

Our basic objectives in this book are threefold:

1. To provide simple, clear, and mathematically uncomplicated explanations of physical concepts and theories of modern physics.
2. To clarify and show support for these theories through a broad range of current applications and examples. In this regard, we have attempted to answer questions such as: What holds molecules together? How do electrons tunnel through barriers? How do electrons move through solids? How can currents persist indefinitely in superconductors?
3. To enliven and humanize the text with brief sketches of the historical development of 20th century physics, including anecdotes and quotations from the key figures as well as interesting photographs of noted scientists and original apparatus.

COVERAGE

Topics. The material covered in this book is concerned with fundamental topics in modern physics with extensive applications in science and engineering. Chapters 1 and 2 present an introduction to the special theory of relativity. Chapter 2 also contains an introduction to general relativity. Chapters 3 through 5 present an historical and conceptual introduction to early developments in quantum theory, including a discussion of key experiments that show the quantum aspects of nature. Chapters 6 through 9 are an introduction to the real "nuts and bolts" of quantum mechanics, covering the Schrödinger equation, tunneling phenomena, the hydrogen atom, and multielectron

atoms, while Chapter 10 contains an introduction to statistical physics. The remainder of the book consists mainly of applications of the theory set forth in earlier chapters to more specialized areas of modern physics. In particular, Chapter 11 discusses the physics of molecules, while Chapter 12 is an introduction to the physics of solids and electronic devices. Chapters 13 and 14 cover nuclear physics, methods of obtaining energy from nuclear reactions, and medical and other applications of nuclear processes. Chapter 15 treats elementary particle physics, and Chapter 16 (available online at **http://info.brookscole.com/mp3e)** covers cosmology.

CHANGES TO THE THIRD EDITION

The third edition contains two major changes from the second edition: *First,* this edition has been extensively rewritten in order to clarify difficult concepts, aid understanding, and bring the text up to date with rapidly developing technical applications of quantum physics. Artwork and the order of presentation of certain topics have been revised to help in this process. (Many new photos of physicists have been added to the text, and a new collection of color photographs of modern physics phenomena is also available on the Book Companion Web Site.) Typically, each chapter contains new worked examples and five new end-of-chapter questions and problems. Finally, the *Suggestions for Further Reading* have been revised as needed.

Second, this edition refers the reader to a new, online (platform independent) simulation package, *QMTools,* developed by one of the authors, Curt Moyer. We think these simulations clarify, enliven, and complement the analytical solutions presented in the text. Icons in the text highlight the problems designed for use with this software, which provides modeling tools to help students visualize abstract concepts. All instructions about the general use of the software as well as specific instructions for each problem are contained on the Book Companion Web Site, thereby minimizing interruptions to the logical flow of the text. The Book Companion Web Site at **http://info.brookscole.mp3e** also contains appendices and much supplemental information on current physics research and applications, allowing interested readers to dig deeper into many topics.

Specific changes by chapter in this third edition are as follows:

- Chapter 1 in the previous editions, "Relativity," has been extensively revised and divided into two chapters. The new **Chapter 1,** entitled "Relativity I," contains the history of relativity, new derivations of the Lorentz coordinate and velocity transformations, and a new section on spacetime and causality.
- **Chapter 2,** entitled "Relativity II," covers relativistic dynamics and energy and includes new material on general relativity, gravitational radiation, and the applications GPS (Global Positioning System) and LIGO (the Laser Interferometer Gravitational-wave Observatory).
- **Chapter 3** has been streamlined with a more concise treatment of the Rayleigh-Jeans and Planck blackbody laws. Material necessary for a complete derivation of these results has been placed on our Book Companion Web Site.
- **Chapter 5** contains a new section on the invention and principles of operation of transmission and scanning electron microscopes.

essay topics covered are recent developments in general relativity, the scanning tunneling microscope, superconducting devices, the history of the laser, laser cooling of atoms, solar cells, and how the top quark was detected. The guest essays are either included in the text or referenced as being on our Web site at appropriate points in the text.

Mathematical Level. Students using this text should have completed a comprehensive one-year calculus course, as calculus is used throughout the text. However, we have made an attempt to keep physical ideas foremost so as not to obscure our presentations with overly elegant mathematics. Most steps are shown when basic equations are developed, but exceptionally long and detailed proofs which interrupt the flow of physical arguments have been placed in appendices.

Appendices and Endpapers. The appendices in this text serve several purposes. Lengthy derivations of important results needed in physical discussions have been placed on our Web site to avoid interrupting the main flow of arguments. Other appendices needed for quick reference are located at the end of the book. These contain physical constants, a table of atomic masses, and a list of Nobel prize winners. The endpapers inside the front cover of the book contain important physical constants and standard abbreviations of units used in the book, and conversion factors for quick reference, while a periodic table is included in the rear cover endpapers.

Ancillaries. The ancillaries available with this text include a Student Solutions Manual, which has solutions to all odd-numbered problems in the book, an Instructor's Solutions Manual, consisting of solutions to all problems in the text, and a Multimedia Manager, a CD-ROM lecture tool that contains digital versions of all art and selected photographs in the text.

TEACHING OPTIONS

As noted earlier, the text may be subdivided into two basic parts: Chapters 1 through 10, which contain an introduction to relativity, quantum physics, and statistical physics, and Chapters 11 through 16, which treat applications to molecules, the solid state, nuclear physics, elementary particles, and cosmology. It is suggested that the first part of the book be covered sequentially. However, the relativity chapters may actually be covered at any time because $E^2 = p^2c^2 + m^2c^4$ is the only formula from these chapters which is essential for subsequent chapters. Chapters 11 through 16 are independent of one another and can be covered in any order with one exception: Chapter 14, "Nuclear Physics Applications," should follow Chapter 13, "Nuclear Structure."

A traditional sophomore or junior level modern physics course for science, mathematics, and engineering students should cover most of Chapters 1 through 10 and several of the remaining chapters, depending on the student major. For example, an audience consisting mainly of electrical engineering students might cover most of Chapters 1 through 10 with particular emphasis on tunneling and tunneling devices in Chapter 7, the Fermi-Dirac distribution in Chapter 10, semiconductors in Chapter 12, and radiation detectors in Chapter 14. Chemistry and chemical engineering majors could cover most of Chapters 1 through 10 with special emphasis on atoms in Chapter 9, classical and quantum

statistics in Chapter 10, and molecular bonding and spectroscopy in Chapter 11. Mathematics and physics majors should pay special attention to the unique development of operator methods and the concept of sharp and fuzzy observables introduced in Chapter 6. The deep connection of sharp observables with classically conserved quantities and the powerful role of sharp observables in shaping the form of system wavefunctions is developed more fully in Chapter 8.

Our experience has shown that there is more material contained in this book than can be covered in a standard one semester three-credit-hour course. For this reason, one has to "pick-and-choose" from topics in the second part of the book as noted earlier. However, the text can also be used in a two-semester sequence with some supplemental material, such as one of many monographs on relativity, and/or selected readings in the areas of solid state, nuclear, and elementary particle physics. Some selected readings are suggested at the end of each chapter.

ACKNOWLEDGMENTS

We wish to thank the users and reviewers of the first and second editions who generously shared with us their comments and criticisms. In preparing this third edition we owe a special debt of gratitude to the following reviewers:

Melissa Franklin, Harvard University

Edward F. Gibson, California State University, Sacramento

Grant Hart, Brigham Young University

James Hetrick, University of the Pacific

Andres H. La Rosa, Portland State University

Pui-tak (Peter) Leung, Portland State University

Peter Moeck, Portland State University

Timothy S. Sullivan, Kenyon College

William R. Wharton, Wheaton College

We thank the professional staff at Brooks-Cole Publishing for their fine work during the development and production of this text, especially Jay Campbell, Chris Hall, Teri Hyde, Seth Dobrin, Sam Subity, Kelley McAllister, Stacey Purviance, Susan Dust Pashos, and Dena Digilio-Betz. We thank Suzon O. Kister for her helpful reference work, and all the authors of our guest essays: Steven Chu, Melissa Franklin, Roger A. Freedman, Clark A. Hamilton, Paul K. Hansma, David Kestenbaum, Sam Marshall, John Meakin, and Clifford M. Will.

Finally, we thank all of our families for their patience and continual support.

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December 2003

Contents Overview

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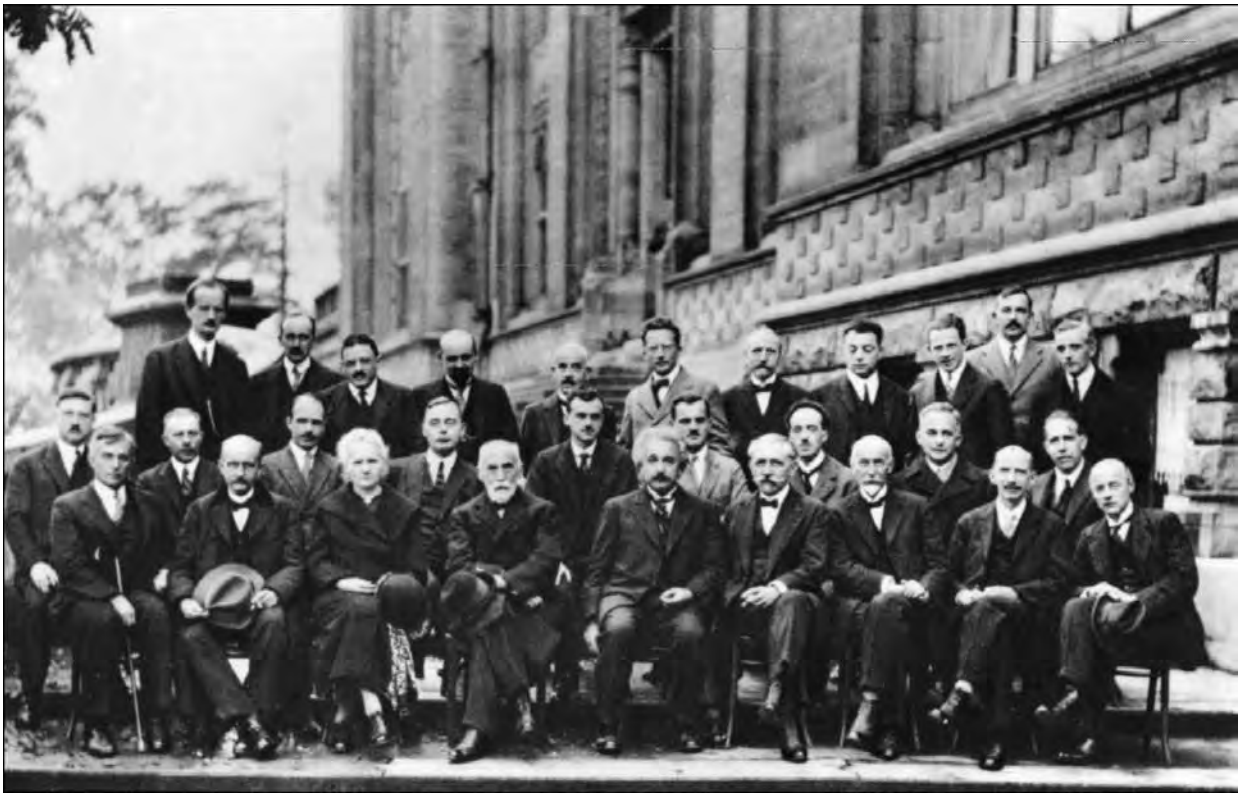

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The "architects" of modern physics. This unique photograph shows many eminent scientists who participated in the Fifth International Congress of Physics held in 1927 by the Solvay Institute in Brussels. At this and similar conferences, held regularly from 1911 on, scientists were able to discuss and share the many dramatic developments in atomic and nuclear physics. This elite company of scientists includes fifteen Nobel prize winners in physics and three in chemistry. (*Photograph courtesy of AIP Niels Bohr Library*)