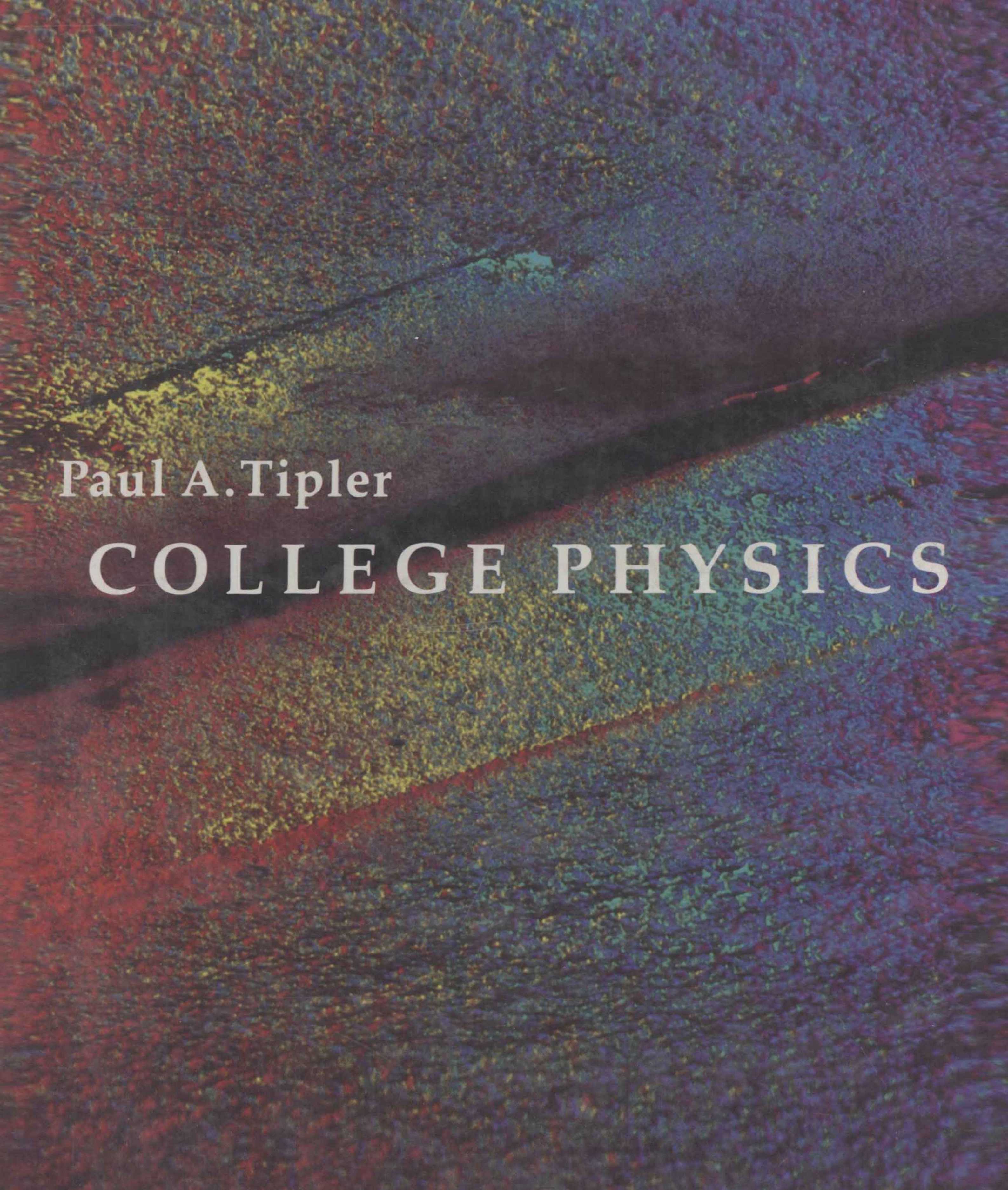

Paul A. Tipler

COLLEGE PHYSICS

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For Becky and Ruth

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Preface

I have written this textbook for the two-semester algebra-based elementary physics course taken by students majoring in biology, environmental sciences, health sciences, premedicine, and other fields. Algebra and a small amount of trigonometry are used, but calculus is avoided. The usual topics in physics are covered in the traditional order that will fit most college courses: mechanics (Chapters 2 to 10), thermodynamics (Chapters 11 to 14), vibrations and waves including sound (Chapters 15 to 17), electricity and magnetism (Chapters 18 to 23), optics (Chapters 24 to 27), and modern physics (Chapters 28 to 33). Although the sequence of topics is standard, there are some features that are not often found in other books. A section on thermal energy and metabolic rate is included in Chapter 6 on work and energy to relate this subject to the familiar experience of students. Chapter 7 (Impulse, Momentum, and Center of Mass) includes a section on jet propulsion with a qualitative description of rocket motion. There is an entire chapter on gravity (Chapter 9), with a discussion of satellite motion and the problem of escaping the earth. Viscous flow is discussed in Chapter 10, and the equations for fluid flow, heat conduction, and electrical conduction are written in the same form so as to bring out their similarities. The chapter on the second law of thermodynamics (Chapter 14) relates entropy to the loss of available energy and to disorder and probability. The section on vibrations and waves (Chapters 15 to 17) follows thermodynamics, where it would naturally conclude the first semester. However, this material could easily be combined with the section on optics (Chapter 24 to 27) and taught either before or after the section on electricity and magnetism if desired.

In recent years there have been many textbooks with special sections or chapters that emphasize the application of physics to the life sciences. This is not one of them. I find that the physical principles are often lost in the maze of applications. I believe that these students are best served by a clear exposition of the principles of physics with many worked-out examples. I discuss applications of these principles to other fields of science or to everyday experience at the beginning of a section to motivate the learning of these principles or at the end of the section to illustrate their wide applicability.

In writing this text I have taken into account the important differences between the students taking this course and those taking the calculus-based course. The first is that most of these students will not take any more physics; in particular, they will not take a separate course in modern physics. For this reason, a significant part of the text is devoted to topics in modern physics. Secondly, these students have less need for, and very much less interest in, the detailed development of physics results. This does not mean that all derivations are omitted. It does mean, however, that more emphasis is placed on the plausibility of a result and its applications than on a mathematical derivation. Often a result is stated, its plausibility is discussed, and examples of applications are shown before a simple derivation is given. I have not hesitated to use special situations to "derive" an important result, or simply to state a plausible result without any derivation. Qualitative arguments are given wherever possible, and detailed mathematical analysis is avoided. Finally, many of these students are very anxious about using mathematics and solving problems. To help these students overcome their anxiety, problem solving is discussed with worked-out examples in Chapter 1, and again in Chapter 4 in conjunction with using Newton's laws. There is also a detailed review of the mathematics needed for the course in Appendix A.

One of my goals in teaching this course has been that students should enjoy their experience in learning physics. To make the text more fun, I have included chapter-opening quotations, many photographs (including movie stills), and cartoons. In addition, extensive use of lecture demonstrations is highly recommended both to illustrate the physics and to add excitement to the classroom. (To aid instructors, the *Instructor's Resource and Solutions Manual* includes chapter-by-chapter suggestions for classroom demonstrations.)

Within each chapter, there are questions at the ends of sections. Some are routine and can easily be answered from the material in the preceding section. Others are open-ended and can serve as a basis for classroom discussion. At the end of each chapter is a review section. This includes learning objectives, which list the information and skills that should have been learned from reading the chapter; a checklist of words and phrases that students are asked to "define, explain, or otherwise identify"; and a set of true-false questions. The page number where the definition of the term is given appears after each item in the checklist, and answers to all the true-false questions are given in the back of the book. Following the review section, there is an extensive set of exercises organized by the sections within the chapter. These exercises are not difficult, and each involves material in that section of the chapter only. The exercises are followed by a shorter set of problems. The problems tend to be more difficult than the exercises and require the student to assimilate material from the entire chapter. Answers to all the odd-numbered exercises and problems are given at the back of the book. (Detailed solutions are given to all the exercises and problems in the *Instructor's Resource and Solutions Manual.*) I suggest the assignment of many more exercises than problems; the exercises are designed to build the student's self-confidence, which can be easily destroyed by too many challenging problems. It would not be unreasonable to assign only exercises in the required homework with a few optional problems to challenge the better students.

Fifteen essays are presented for the enjoyment and enlightenment of students and instructors. Three are biographical (on Isaac Newton, Albert Einstein, and Benjamin Franklin), many are on applications (for example, xerography, lasers, and nerve impulse conduction), and others are on topics of current interest (for example, thermal pollution, energy resources, and the Voyager exploration of the solar system.) There are no exercises or problems associated with the essays.

For the sake of completeness and flexibility, the book contains more material than can be covered in two semesters. Some sections or chapters must therefore be omitted or skimmed over. One method for broadening a course (while sacrificing some of the depth) is to assign a chapter or section to be read without assigning the associated exercises. I would recommend this to those who are tempted to omit Section 15-5 on damped and driven oscillators because the important ideas of resonance should be presented to students as early as possible. The inclusion or omission of certain topics naturally depends on the judgment of the instructor and the particular needs of the students. For a two-semester course, I would suggest the omission of some of the following: Sections 5-5 (Drag Forces), 6-7 (Thermal Energy and Metabolic Rate), 7-5 (Jet Propulsion), 8-4 (Rolling Bodies), 8-5 (Motion of a Gyroscope), 9-5 (Escaping the Earth), 9-6 (Potential Energy, Total Energy, and Orbits), 10-5 (Surface Tension and Capillarity), 10-6 (Fluids in Motion and Bernoulli's Equation), 10-7 (Viscous Flow), 13-3 (The van der Waals Equation and Liquid-Vapor Isotherms), 13-4 (Humidity), 14-5 (The Heat Pump), 14-6 (Entropy and Disorder), 14-7 (Entropy and Probability), 17-5 (Harmonic Analysis and Synthesis), 18-5 (Gauss' Law), 18-6 (Electric Dipoles in Electric Fields), 20-6 (*RC* Circuits), 21-5 (Ampere's Law), 21-6 (Current Loops, Solenoids, and Magnets), 21-7 (Magnetism in Matter), 22-2 (Motional emf), 22-5 (*LR* Circuits and Magnetic Energy Density), 24-6 (Polarization), 27-7 (Diffraction Gratings), 29-4 (Compton Scattering), 31-4 (Molecular Bonding), 31-5 (Molecular Spectra), 32-3 (Nuclear Reactions), and Chapters 23 (Alternating Current Circuits), 26 (Optical Instruments), and 28 (Relativity).

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Paul Tipler

To the Student

We have always been curious about the world around us. Since the beginnings of recorded thought, we have sought ways to impose order on the bewildering diversity of the events we observe. This search for order has taken a variety of forms: one is religion, another is art, and a third is science. Although the word *science* has its origins in a Latin verb meaning "to know," science has come to mean not merely knowledge but specifically knowledge of the natural world. Most importantly, science is a body of knowledge organized in a specific and rational way.

The roots of science are as deep as those of religion or art, but its traditions are much more modern. Only in the last few centuries have there been methods for studying nature systematically. They include techniques of observation, rules for reasoning and making predictions, the idea of planned experimentation, and ways for communicating experimental and theoretical results—all loosely referred to as the *scientific method.* An essential part of advances in our understanding of nature is the open communication of experimental results, theoretical calculations, speculations, and summaries of knowledge. A textbook is one form of open communication. An introductory textbook like this has two purposes. It is designed, first, to introduce newcomers to material that is already widely known in the scientific and technical community and that will form the basis of their more advanced studies. It also serves to acquaint students not majoring in science with information and a way of thinking that are having a cumulative effect upon our way of life.

Although we now think of science as being divided into several separate fields, this division occurred only in the last century or so. The separation of complex systems into smaller categories that can be more easily studied is one of the great successes of science in general. Biology, for example, is the study of living organisms. It can be further separated into zoology, botany, paleontology, macrobiology, microbiology, and so forth. Chemistry deals with the interaction of elements and compounds. Geology is the study of the earth. Astronomy is the study of the solar system, the stars and galaxies, and the universe as a whole. Physics deals with matter and energy, with the principles that govern the motion of particles and waves, with the interactions of particles, and with the properties of molecules, of atoms and atomic nuclei, and of larger scale systems such as gases, liquids, and solids.

Some consider physics the most fundamental science because it is the basis of biology, chemistry and all the other fields of science. Originally, all of these subjects were considered a single science called natural philosophy. Even today, with such a high degree of specialization, the boundaries between the various fields of science are not sharp, and we have many interdisciplinary fields such as biophysics, physical chemistry, biochemistry, and chemical physics.

In this book we shall study the usual subtopics of physics: mechanics, sound, light, heat, electricity, magnetism, atomic physics, and nuclear physics. These seemingly diverse subjects are unified by a few important laws and concepts, for example, Newton's laws of motion and the conservation of momentum and energy. The study of physics has wide application. Architects, nurses, physical therapists, engineers, doctors, musicians, and many others need to know about such subjects as heat transfer, fluid flow, sound waves, light, radioactivity, the balance of forces, and stresses in buildings or in bones. Physics also has wide applicability to questions in everyday life. Why does a car skid rounding a curve? In what sense are astronauts weightless? Why does sound travel around corners while light does not? Why does an oboe sound different from a flute playing the same note? Why do things appear larger through a magnifying glass? How does radioactive carbon dating work? Why is the sky blue? Why do metal objects feel colder than wood ones at the same temperature? These and countless other questions about our fascinating world can be answered from a basic knowledge of elementary physics.

A textbook is only one tool for learning physics. A good teacher, lecture demonstrations, films, and experimental work in the laboratory are also indispensible. Outside reading is highly recommended. While you are learning about the topics covered in your physics course, you should be broadening your familiarity with contemporary physics by reading widely among the many excellent popular and semipopular accounts of modern science such as those in *Scientific American.*

Like any other subject, physics has its own vocabulary that must be learned. Many common words such as *force, work,* and *momentum* have special meanings in physics. At the end of each chapter, there is a list of the new terms that have been introduced, allowing you to test yourself to see if you can identify them and explain their meaning.

An important part of learning physics is learning to solve problems. Most physics problems are stated in words but require the solving of mathematical equations. The only mathematics you will need to use for this text are algebra and trigonometry. A review of these subjects is given in Appendix A. Many students find the problem-solving aspect of physics a bit intimidating. Section 6 in Chapter 1 provides some hints and useful general techniques for working problems. More specific methods for solving problems using Newton's laws of motion are discussed in Section 6 of Chapter 4. A good way to gain practice in problem solving is to try to work through the examples in the text without referring to the solutions given. When you finish or get stuck, read through the worked example. Don't be discouraged if you have difficulty. Some of the examples introduce a new method of solution and some cover famous results and are an extension of the text. In these cases, you cannot expect to work the example without a great deal of thought and effort. At the end of each chapter are exercises and problems. (Chapters 1 and 33 have only exercises.) The exercises require material from just one section in the chapter and can usually be solved in a single step. If you have difficulty with an exercise, it is an indication that you should reread the corresponding section. The problems are much more challenging and often require assimilating material from throughout the chapter (and previous chapters) and applying it to a new situation. It is perfectly natural to have difficulty with many of the problems.

To supplement the exposition of basic principles, there are many essays throughout the book. These are for your pleasure and enlightenment and have no exercises or problems associated with them.

Your enjoyment of physics will be enhanced if you keep your eyes and ears open for examples in your everyday life of the physics you are learning. You should find many—the change in the sound of a passing car, the vibration of tree branches in the wind, the colored patterns in soap bubbles, the walking of water bugs on the surface of a pond, and so forth. See if you can explain the phenomena you observe using the principles of physics that you have learned. If you have questions, ask a fellow student or your instructor. One of the joys of learning physics is the greater awareness, understanding, and appreciation it brings of the world around us. I hope that this book will serve as your guide to that pleasure.

Berkeley, California
February 1987

Paul Tipler

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