Preface
to the Instructor

The students for whom this book has been written typically have one exposure to physics—this course. Given the enormous breadth of interesting material, a major challenge facing any instructor is the selection of topics. As the twentieth century draws to a close, it seems appropriate that the enormous strides taken in modern physics be meaningfully integrated into the intellectual traditions of the past. Consequently, this book presents a somewhat different approach to the topics and concepts typically included in a course at this level.

ORGANIZATION

The book is divided into five major units. Each unit begins with a concept in classical physics and builds toward a topic that generally falls into the category of modern physics. The first, *Space and Time,* begins with a fairly traditional presentation of position and motion, continues with classical relativity, and concludes with an introduction to the special theory of relativity. The care we have taken to integrate the concept of reference frame into descriptions of position and motion lays a strong foundation for the results of special relativity. Unit 2, *Interaction and Force,* begins by describing interactions and how we know they occur, next looks carefully at forces and Newton's Laws, and closes with a discussion of the four fundamental interactions in nature and current attempts to build a unified theory. Students often find the concept of force to be one of the more elusive ideas in physics. We have taken special care in developing the concept of force carefully. Unit 3, *Energy,* uses the concepts of kinetic and gravitational potential energy to introduce energy conservation and the various forms of energy that have emerged from our commitment to the principle of energy conservation. The discussion then moves to thermal energy and the laws of thermodynamics. We conclude with a look at the atomic and molecular view of matter and how kinetic energy is related to thermal phenomena on the atomic scale. Wave motion, classical and quantum, is the topic of Unit 4, *Waves and Particles.* It begins with mechanical waves, presents diffraction and interference, and then shows how experimental results led to wave-particle duality and quantum mechanics. The final section, *From Electricity to the Nucleus,* starts with the ideas of a circuit and electrical energy, looks at electromagnetism and methods of generating electrical energy, and then concludes with discussions of converting nuclear energy into electricity. Throughout the book, in an attempt to show both the unity and continuity of physics, modern ideas are integrated with the ideas that preceded them in the logical development of physical concepts.

Philosophical, social, and historical discussions are included in the development of the concepts when it seems appropriate. In addition, four interludes and an epilogue treat these aspects of physics in some detail.

OUR AUDIENCE

In this text, we make a few assumptions. First, we assume that many of the students' prior experiences can help them learn physics. So, we employ an inductive approach, and try to start each major section with some common experiences and move to generalizations and concepts. Our second assumption is that the students in this course have limited proficiency with mathematics. However, we cannot completely separate mathematics from physics. (One cannot understand a conservation law unless one sees that a value does not change.) Thus we expect the students to use arithmetic to evaluate some algebraic expressions but not to perform algebraic manipulations. Our final assumption is that the students must do in order to learn. Three different levels of written exercises and a set of activities conclude every chapter. In addition, Self-Checks (with answers at the ends of the chapters) are scattered throughout the book. (See *Preface to the Student.*)

Throughout the book we have used metric units. SI units are used almost exclusively. The only exceptions are for pedagogical reasons. (For example, N/m^2 seems to emphasize the meaning of pressure better than pascals.) Our experience has been that essentially all 18–25-year-old students have been taught the metric system and have a reasonably good feeling for the sizes of units such as the meter and kilogram. (Few have a good idea of the size of a joule, but they have no better feeling for a calorie or BTU.) Older students may not have any formal training in the metric system, but they seem to have picked it up from interactions with younger people, usually their children. Thus we have used only metric units and presented conversions with traditional U.S. units only in an appendix.

ACKNOWLEDGMENTS

We received help from a variety of people as we wrote this book. First and foremost we owe a special thanks to all the students (approximately 1000 of them) who used preliminary editions of the manuscript and were always more than willing to tell us when something was not quite presented in the clearest possible way. In addition, we relied heavily on the reviews of Murray Alexander, Milo V. Anderson, Claire Chapin, Russell Coverdale, James R. Crawford, Dewey Dykstra, Jr., David J. Ernst, John Giles, John S. King, Bernard Kramer, James A. Lock, Bernard F. Long, John E. Maling, Kaye Martin, Allan Miller, Fernando B. Morinigo, Carl J. Naegele, Barton Palatnik, Paul Phillipson, D. L. Rutledge, Lawrence C. Shepley, Jack White, and S. J. Yarosewick. Our colleagues at Kansas State University and Marymount College were seemingly infinite sources of helpful suggestions. One of us (D. Z.) also enjoyed the hospitality of the University of Utah for a sabbatical leave during which time part of this text was written. At Benjamin/Cummings, Andy Crowley provided the editorial guidance to bring this book to a successful completion, and Robin Fox's careful reading of the entire manuscript helped us tighten the final version. Sue Harrington and Mimi Hills directed the manuscript through production. Finally, we have been greatly influenced by discussions with many of our colleagues on subjects ranging from how students think to the principles of physics. We thank all of them and especially acknowledge the influences of Bob Fuller, Paul Hewitt, and Bob Karplus.

No set of acknowledgments would be complete without paying special tribute to our spouses, who only occasionally complained about the amount of time we spent on this project.

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Preface
to the Student

As you begin your study of physics you probably have two questions.

What do I need to know before I start?
How can I learn physics most effectively?

Because students' learning styles vary, no unique answers can be given to these questions. However, our students have found some general guidelines to be useful.

We assume that you have not taken a formal physics course before starting this one. However, we also believe that you already know a lot of physics. You have learned this physics just by living and doing your normal, everyday activities. What you probably do not know are the underlying concepts that connect and explain your many observations and experiences. So, the main items you need to bring to your study are your experiences and observations.

Physicists use two languages—ordinary speech with some specialized vocabulary and mathematics. As you study physics, you will pick up the vocabulary. We have tried to keep new words, as well as familiar words with new meanings, to a minimum. Thus the vocabulary of physics should not hinder your learning.

We have also kept the mathematics at a level with which you should feel comfortable. We do not expect you to solve algebraic equations. We do expect you to be able to use arithmetic to evaluate an algebraic expression. (For example, speed = distance/time; if distance = 10 meters and time = 5 seconds, what is the speed?) Most evaluations involve simple expressions, which you can do in your head. A few may require pencil and paper or an inexpensive calculator. Nothing fancy is required; anything that adds, subtracts, multiplies, and divides will do. Armed with your paper and pencil or your calculator, you will be more than adequately prepared for the mathematics in this book.

As you study physics, your first introduction to new concepts will come from reading and listening. But, that is only the start. Understanding comes from using these ideas to explain observations and problems. An effective way to acquire this understanding involves several steps.

Before each new concept is introduced, we present some common experiences or observations related to the concept. After you have read a description of the new concept, think back on the opening. Try to relate in your own words how the concept explains and ties together the experiences and observations. Also think about your own experiences. Can some of them be explained with your new knowledge? After the introduction of a concept we present some of its applications. Again, read these carefully to follow the reasoning in applying your new knowledge.

Within the text are Self-Checks. These short exercises give you a chance to see how well you have understood the material which you have just studied. Each Self-Check is also a warning. You will need to know this material to understand future concepts. So, complete the Self-Checks and compare your answers with those at the end of the chapter. Only after you have written out the answers to the Self-Checks completely and understood the correct answers are you ready to continue your study of physics.

Your learning becomes more active when you apply your newly acquired knowledge. Exercises at the end of each chapter are designed for this purpose. We have divided the exercises into four groups: Reviewing Chapter Material, Applying the Chapter Material, Extensions to New Situations, and Activities. You cannot learn physics effectively unless you complete at least some of these exercises.

The first exercises, Reviewing Chapter Material, are labeled with a prefix of A and are a series of questions taken directly from the material in the text. The questions ask you to state the ideas of the chapter in your own words. You should be able to complete all the questions for every chapter that you study.

Applying the Chapter Material, with a prefix of B, gives you the opportunity to practice using the concepts in situations that are very similar to the ones presented in the text. Sometimes these exercises involve using a general idea and some logic; other times they will require a calculation or two. In both cases your understanding will improve as you complete the exercises.

Extensions to New Situations, with a prefix of C, enables you to take an idea from the chapter, follow some logical steps, and reach a conclusion that is not stated in the chapter. We do not expect you to do this entirely on your own, so we provide some help. These exercises are where the fun can really begin. You know enough to start with one idea and see where it takes you.

Finally, the Activities present some things you can do—short experiments you can complete at home, books or articles you can read, essays you can write, and so on. They can frequently help more than anything else. Doing is one of the best ways of learning.

Whenever you are working on any of the exercises, you should remember that the underlying question is always: How do the concepts of physics explain this situation? You should not simply state the answer but give an explanation in terms of what you have learned. In physics, Yes is never a correct answer; Yes, because . . . may be correct.

In general, learning physics effectively involves not only reading and listening but also doing exercises and reflecting on your experiences. Next winter when you slip on some ice, do not think "Oh darn, I almost broke my leg," but "Let's see, what forces didn't I consider while walking on the ice?"

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