GENERAL PHYSICS

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Preface

This introductory calculus-based physics textbook is aimed at students majoring in physics, other sciences, and engineering. It is intended to be readable, interesting, accessible to students, and yet comprehensive, with careful and detailed development of physics principles and emphasis on problem solving.

There are, of course, a number of good physics textbooks on the market. Why another one? A major reason is that the first-rate comprehensive texts tend to be dry and formal, and hence often difficult and boring for students. They lack freshness. A common approach is to treat topics formally and abstractly first, and only later (if at all) to come down to earth and relate the material to the students' own experience. This approach may be appealing (it's elegant), but it can slow down the learning process for all but the best students. My approach is to recognize that physics is a description of reality and thus to start each topic with concrete observations and experiences that students can directly relate to. Readers are then led into the more formal and abstract treatment of topics. Not only does this make the material more interesting and easier to understand, but it is closer to the way physics is actually practiced. Historically, we didn't start with the second law of thermodynamics, for example, and then derive all kinds of consequences from it; rather, the law was a generalization of all kinds of phenomena. Yet many textbooks treat topics in physics in that reversed fashion. I have avoided that dogmatic approach of stating principles and then deriving conclusions; instead I develop the principles as generalizations from specific observations.

I have tried, also, to avoid pedantic treatments by making discussions clear and concise, and to eliminate a common fault of dragging out small points to the extent of making them seem big (thus confusing students). On the other hand, I have also tried to avoid the problem of leaving certain topics "hanging," with students wondering "why did we study that?" I thus have tried to indicate why each topic is important, and to bring each topic to completion. We study static forces in structures, for example, partly because real materials are elastic and also can fracture; so I have included the latter topics in the statics chapter. After saying this, I must mention some exceptions: I have treated a very small number of topics only very briefly (such as Maxwell's equations in differential form) and have not developed them fully. The point, in these few instances, is to let the student know of their existence. When they meet them again in the future they will at least have seen them before and won't be totally ignorant. A longer treatment here could not be done at an appropriate level and/or would have made the book too long.

The order of topics is more or less traditional, but the book allows for considerable flexibility in this order. It begins with mechanics (Chapters 1–14), including fluid mechanics, followed by waves (Chapters 15–16), kinetic theory and thermodynamics (Chapters 17–21), electricity and magnetism (Chapters 22–33), and light (Chapters 34–38). Finally there are five chapters on modern physics: special relativity (Chapter 39), quantum theory and atomic physics, including material on lasers and condensed matter physics (Chapters 40–41), nuclear physics (Chapter 42), and elementary particles, including brief discussions of quarks, charm, QCD, the "standard model," and grand unified theories (Chapter 43). The topics in modern physics are treated at an appropriate level (that is, not too difficult) and necessarily briefly, but in enough detail, I hope, to whet the appetite of the students and give them a taste of what is happening in physics today. Nonetheless, the real emphasis in this book is the 38 chapters on classical physics.

The tradition of beginning with mechanics is sensible, I believe, since mechanics was developed first, historically, and since so much else in physics depends on it. Within mechanics there are various ways to order the topics. The order of the chapters here does not have to be followed precisely. Statics, for example, can be covered either before or after dynamics. One of my reasons for placing statics after dynamics is that from experience I have found that students have trouble with the concept of force without motion. Once they have understood the connection between force and motion, including Newton's third law, they seem to be better able to deal with forces without motion. Furthermore, placing statics later allows full development of the concept of torque, which is also crucial for statics and can be difficult to understand in the absence of motion. Finally, statics is really a special case of dynamics — and we study it largely so that we can prevent static structures from becoming dynamic (falling down). Nonetheless, statics (Chapter 11) has been written so that it could be covered earlier, if desired, before dynamics, after a brief introduction to vectors.

Another option is the position of the chapters on light. They are placed after the chapters on electricity and magnetism and electromagnetic waves, as is typical. However, light could be treated immediately after the chapters on waves and sound (Chapters 15 and 16), thereby keeping the various types of wave motion in one place. Another position choice involves special relativity (Chapter 39), which is treated after electromagnetic waves and light have been covered. Relativity could, however, be covered along with mechanics, say after Chapter 8, since it mainly depends (except for the optional Section 39–2) on material only through Chapter 8.

Much attention is given to problem solving. Explicit hints on how to attack problems are given in several places early in the book, notably in Sections 2–7, 4–8, and 4–10 (whose title is "Notes on Problem Solving"). The last-named section is placed after the students have had some experience wrestling with problems and hopefully will then be motivated to read and pay attention to this section. Section 4–10 can, of course, be covered much earlier if an instructor so desires.

The large selection of worked-out examples, as well as problems, covers a wide range, and I hope are more interesting than is usual; they cover not only physics, but applications to engineering, other sciences, and everyday life. The approximately 2000 problems are arranged by section and are ranked according to difficulty: level I problems are simple, usually plug-in, types designed to give students confidence, and sometimes to illustrate a simple but interesting point or application; level II are normal problems, requiring thought and often a combination of two or more concepts; level III problems are the most difficult. The arrangement by section number means only that those problems depend on material up to and including that section — earlier sections and chapters are often relied upon, particularly in level II or III problems. The ranking of the problems by difficulty (I, II, III) is necessarily subjective and is intended only as a guide. Level II problems, particularly, are of a very wide range. Level III problems will challenge even superior students. It's a good idea to check level III problems carefully before including them in regular homework assignments. Answers to odd-numbered problems are given at the back of the book. Each chapter also contains a set of questions (about 1200 in total) requiring verbal answers. SI units are used throughout; British units are defined, but not used. A limited number of problems requiring a programmable calculator (or computer) are included in a number of chapters, as is a simple discussion (in optional Section 2–10) on how to do numerical integration.

It is assumed that the readers have taken calculus or are taking it concurrently. The derivative is first introduced at the end of Chapter 2 (kinematics) in an optional section. This material can easily be covered later, say when the integral is first discussed in Chapter 6 (work and energy). Calculus is treated gently and slowly, especially at first. In fact, throughout the book, each topic is begun at a fairly low level so that understanding is accessible to a wide range of students. The rigor normally expected at this level is quickly reached; and for the most motivated students there are advanced topics (noted as optional by an asterisk), as well as a few rather difficult problems (ranked III, see above). Mathematical tools are introduced where they are first needed: the derivative and integral as mentioned above, vector addition in Chapter 3, the dot product and cross product in Chapters 6 and 10, respectively, and so on. I believe this method is preferable to putting a lot of math in Chapter 1, because it provides motivation for the student (they see immediately, for example, why the dot and cross products are defined as they are). A few topics (such as dimensional analysis and order-of-magnitude estimating) are placed in Chapter 1 to make them more visible rather than burying them at some arbitrary place in the book. These could be covered later, when the need arises.

This book contains more material than can be covered comfortably in a shorter course of, say, one year; nonetheless it can be readily adapted to such a course. Sections marked by an asterisk are considered optional. These sections contain slightly more advanced physics material, or material not usually taught at this level, or interesting applications. They contain no material needed in later chapters (except, perhaps, in later optional sections). This does not imply that all nonstarred sections must be covered; there remains considerable flexibility in the choice of material to suit the needs of students and instructors. For a short course, in addition to optional sections, much or all of Chapters 10 (except Sections 10–1 and 10–2), 11, 12, 13, 23, 31, 32, 39–43 could be omitted, as well as selected parts of Chapters 8, 16, 27, 29, 33, 35–38. The topics not covered in class can still be read by students, and the book thus provides a valuable resource as a reference book because of its wide range of coverage.

It is necessary, I feel, to pay careful attention to detail, especially when deriving an important result. Whether it is a verbal discussion, or a mathematical one, I have aimed at including all steps in a derivation so that students don't get bogged down in details and then fail to understand the concept as a whole. I have tried to make clear which equations are general, and which not, by explicitly stating the limitations of important equations in brackets next to the equation, such as

$$x = x_0 + v_0 t + \tfrac{1}{2}at^2. \qquad \text{[constant acceleration]}$$

Rotational motion is difficult for most students. As an example of attention to detail (although this is not really a "detail"), I have carefully distinguished the position vector (**r**) of a point and the perpendicular distance of that point from an axis (I call this R, using a small capital). This distinction (which enters particularly for torque and angular momentum) is often not made clear in other books; some books use r for both without distinguishing—and this can be very confusing to students. Also, I have treated rotational motion by starting with the simpler situation of rotation about an axis (Chapter 9), including angular momentum and rotational kinetic energy; only in Chapter 10 is the more general rotation about a point dealt with, and this slightly more advanced material (except Sections 10–1 and 10–2 on the vector product and the torque vector) can be omitted if desired.

Among other unusual treatments is Chapter 29, Sources of Magnetic Field: here, in one chapter, are discussed the magnetic field due to currents (including Ampère's law and the law of Biot-Savart) as well as magnetic materials, ferromagnetism, paramagnetism and diamagnetism. This has resulted in a treatment that is clearer, briefer, and more of a whole, and all the content is there. Another is the treatment of conservative forces and conservation of energy in Chapter 7, which is done carefully (showing explicitly, for example, why $W_{1\to 2} = -W_{2\to 1}$ for a conservative force) but without the long-winded confusion that is common. There is a discussion of diffusion (Chapter 18), unusual for a book at this level, but an important topic; not only is it done more clearly and simply than in more advanced books, but "real" diffusion is discussed, not just "self-diffusion."

I wish to thank the many people who contributed in various ways to making this a better book. The professors who read the manuscript and offered many excellent comments include James B. Gerhart, Edward F. Gibson, Robert B. Hallock, Gordon E. Jones, Terrill W. Mayes, Michael A. Morrison, Edward B. Nelson, Norman Pearlman, Sheridan Simon, Gilbert H. Ward, and Thomas H. Wood. Special thanks go to John Heilbron who offered valuable suggestions for clarifying the wonderful history of our subject. Special thanks also to Professors Richard Marrus and Howard Shugart for many helpful discussions, as well as for their hospitality at the University of California, Berkeley. Finally, I wish to thank the many people at Prentice-Hall who worked on this project, particularly Logan Campbell, Doug Humphrey, Linda Mihatov, Janet Schmid, and the patient and perspicacious development editor Ray Mullaney. The responsibility for all errors lies, of course, with me. I welcome comments and corrections.

Douglas C. Giancoli

Notes to Students and Instructors on the Format

1. Sections and subsections marked with a star (*) are considered optional (see the Preface).
2. The customary conventions are used: Symbols for quantities are italicized (such as *m* for mass), whereas units are not italicized (m for meter); boldface (**F**) is used for vectors.
3. Important terms are italicized where they are introduced, and the most important are in boldface (such as *coefficient of friction* and **acceleration**).
4. Few equations are valid in all situations. Where practical, the limitations of important equations are stated in square brackets next to the equation.
5. Worked-out Examples and their Solutions in the text are set off with a vertical colored line in the margin.
6. Each chapter ends with a Summary, giving a brief review of important concepts and terms (the most important ones are italicized here). The Summaries are not intended to give an understanding of the material, which can only be had from a study of the chapter.
7. Following the Summary in each chapter are sets of Questions that students should attempt to answer (to themselves at least) and Problems arranged according to section and difficulty (see the Preface). Questions and Problems that relate to optional sections are starred.
8. The appendixes contain useful mathematical formulas (including derivatives and integrals), a discussion of polar coordinates, and a table of isotopes with atomic masses and other data. Tables used frequently are located inside the front and back covers.
9. The extensive Index can be a useful tool. For example, it can be used to look up concepts or words whose meanings have been forgotten.

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