INQUIRY INTO Physics

Third Edition

Vern J. Ostdiek Donald J. Bord

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THIRD EDITION

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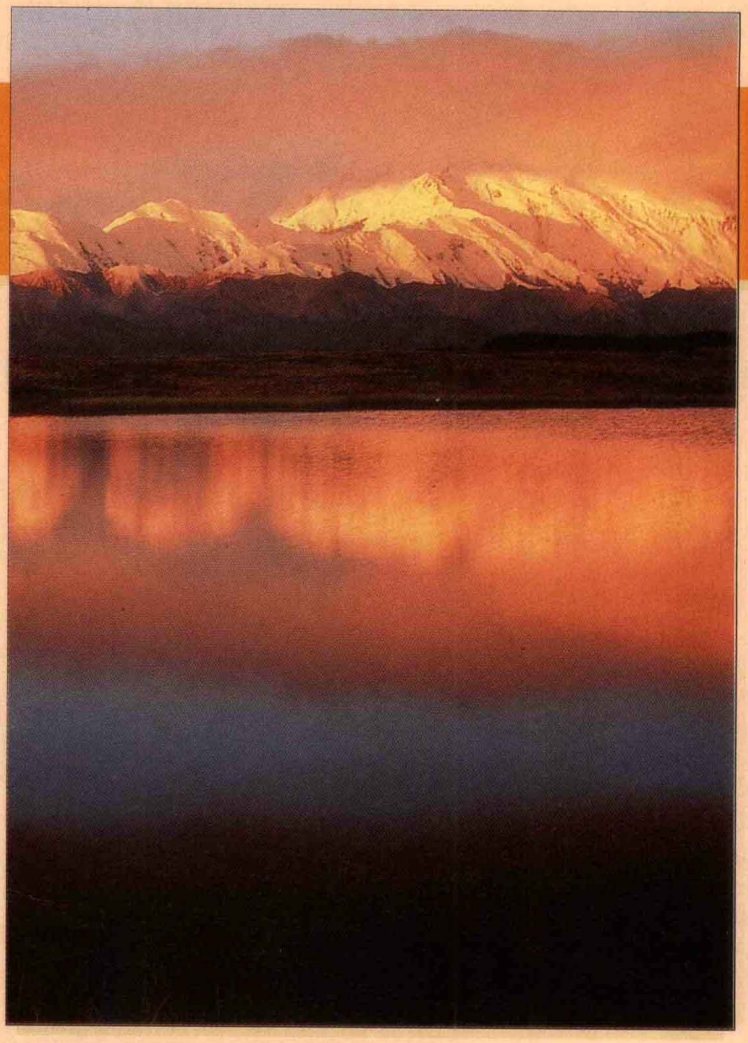

To Freeman Dyson,
for being an inspiration
to physicists who strive to be authors.

Vern Ostdiek

To my father, Richard Ford,
and my son, Jeffrey Tyler—for all they have taught me
about the beauty, wonder, and function of Nature.

Don Bord

Preface

This is the third edition of *Inquiry into Physics,* a textbook for students taking perhaps their first and only physics course. Throughout the decade-long evolution of this book, we have tried to keep in mind a few basic tenets that first guided us as teachers. Physics can be presented in a way that is both accessible and interesting to everyone. The simple mathematics that students already know can enable them to see how useful and powerful the quantitative side of physics is. Writing about physics is, first and foremost, writing. In their exposition, authors, like teachers, should strive to be clear but not boring, precise but not pedantic, interesting but not superficial, evocative but not ambiguous. Images are an important part of learning and understanding, and a book's illustration program deserves the same care that the writing does. The history of discovery is a fascinating, and too often neglected, part of physics. A great way to learn is by example: to see how knowledge and understanding emerged from hard work, insight, foresight, luck, and brilliance, both of famous scientists in the limelight and of quite ordinary people laboring in obscurity. While one of the oldest of intellectual pursuits, physics is very much alive and influential in today's world—there are still many mysteries out there to be solved.

The third edition of *Inquiry* includes a number of major changes:

- Full color is used throughout the text. Nearly all drawings have been redone, with an emphasis on increased clarity and precision. (A few of the authors' favorite works by Denny McCarthy have been retained from the previous editions.) Dozens of new color photographs are included.
- An *Epilogue* has been added, which combines an introduction to the general theory of relativity with cosmology in a way that emphasizes how necessary it is to bring together concepts from many different branches of physics to address the most fundamental questions about the universe.
- *Concept Maps,* visual summaries of selected material in the text, show comparisons and interrelationships in a unique and meaningful way.
- Two *Physics Potpourris* now appear in each chapter, including eight new ones covering subjects like chaos and synthesizers.
- Five *Prologues* are new, using topics such as particle accelerators and airships to introduce chapter material.
- A second *Learning Check* has been added near the end of each chapter.
- As is the trend in textbooks, the new edition is published in paperback.
- *Study Skills,* a short section containing tips to help students improve their academic performance, follows this *Preface.*
- New, revised, and updated material appears throughout the book, from descriptions of recent progress in fusion research, telescope technology, and applications of sound, to obituaries of "tabletop fusion" and the superconducting supercollider.
- New *Questions, Problems,* and *Challenges* have been added as well.

The basic organization of the text remains unchanged, with topics sequenced in traditional order. Each of the 12 chapters is built around the following features:

- *Prologue.* Motivates the reader by showing how a topic of current interest involves the ideas presented in the chapter.
- *Examples.* Worked problems that illustrate the roles of physics and simple mathematics in real-life situations.
- *Do-It-Yourself* and *Do-It-Together Physics.* Experiments and exercises that give students the chance to see and do physics, without using special equipment.

- *Learning Checks.* Simple self-quizzes near the middle and near the end of each chapter, designed to test a reader's basic comprehension of the material.
- *Physics Potpourris.* Self-contained discourses on selected topics drawn from astronomy, the history of science, biophysics, and other areas. (Two per chapter.)
- *Concept Maps.* New visual displays of the relationships between concepts.
- *Historical Notes.* The final section in each chapter presents a look at the human side of physics by describing the lives and work of those who discovered and developed concepts presented in the chapter.
- *Summary.* A brief review of the major points in the chapter.
- *Summary of Important Equations.* An annotated list of the key equations in the chapter.
- *Questions.* Queries that check basic understanding of the material and the reader's ability to extend that understanding to new or hypothetical situations.
- *Problems.* Simple mathematical exercises based on realistic applications of physics.
- *Challenges.* More advanced questions and problems that test the reader's mastery of the material at a deeper level. Many can be used as starting points for class discussions.

In the Appendixes and end sheets you will find: *Table of Conversion Factors and Metric Prefixes, Periodic Table of the Elements, Winners of the Nobel Prize in Physics, Math Review, Answers* (to *Learning Checks* and to odd-numbered *Problems* and *Challenges*), *Glossary*, and *Suggested Readings*.

There is more than enough material in the text for a typical one-semester course. However, about 30 of the more specialized sections can be omitted without affecting later material. Specifically, these include the *Historical Notes,* Sections 2.8, 2.10, 4.6, 4.7, 5.2, 5.5, 5.7, 6.4, 6.5, 6.6, 8.4, 8.7, 9.2, 9.4, 9.6, 10.7, 10.8, 11.6, and 11.7.

In the process of revising *Inquiry Into Physics,* we were helped along the way by many people. Doug Brothers and Scott Baird at Benedictine College provided access to equipment and space. At the University of Colorado, Nimal Gamage served as a volunteer computer consultant, and Mike Thomason lent equipment. At UM-Dearborn, continuing thanks go to Paul Zitzewitz for his unselfish sharing of novel teaching techniques and physics resource information, and to John Devlin, with whom one of us (DJB) has annually team-taught a course using *Inquiry,* for bringing to light several errors in the text and for his insightful comments on how to present this material in more engaging and effective ways. Special thanks are due to Jeff Prentis for his careful review of and helpful comments on the *Physics Potpourri* on chaos.

Once again West Publishing assembled a team of committed professionals to produce the final product. Jerry Westby managed the entire revision, somehow keeping everyone working together though scattered over four time zones. Dean DeChambeau organized the reviews and the ancillaries. Tammy Moore and Holly Henjum handled the production process with skill and dedication. Randy Miyake converted drawings and descriptions into colorful art, patiently changing and correcting numerous drafts to please two fastidious authors. Candace Schau and Nancy Mattern produced original *Concept Maps,* perhaps the first ever for a physics textbook. Mary Steiner and her co-workers promoted the finished product. To these people and to others we have undoubtedly missed, thank you.

We wish to express our gratitude to the following instructors for reviewing the second edition and providing comments, corrections, and suggestions.

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One final note: While going through the book, you may notice that many of the photographs appear to be, shall we say, "homemade." That is because they are. Having long ago realized that his work would never appear in *National Geographic,* one of us (VO) jumped at the opportunity to put his old Pentax to use. The do-it-yourself photo safaris were a welcome respite from the tedium of proofreading this manuscript. It is hoped that the results do not detract too much from the excellent work of the "real" photographers and artists that grace the pages of this book.

Study Skills

The beginning of a new semester is an ideal time to think about the process of learning, and about ways to improve your academic performance. Perhaps over the years you have developed some poor habits, or you don't quite know how to approach a course in a field somewhat removed from what you are used to. We offer the following suggestions for you to consider adopting as your "new semester's resolutions." They are relatively simple ideas that may help you improve your efficiency and your effectiveness as a student. The goal is to adopt habits that will allow you to learn more, perform better on exams, and earn higher marks, without necessarily expending more time or effort. Some make specific reference to physics courses or to this textbook, but most are quite general and could help in any course you take. We first present two general keys to success, and then some specific tips concerning the day-to-day aspects of taking a course.

Keys to Success

- *Avoid procrastination.* (We wanted to write this section later, but we successfully avoided that temptation.) In your studies, procrastination is a dangerous habit. Putting off your work may provide temporary satisfaction because you thereby avoid something you do not want to do, but in the long run procrastination leads to stress, mistakes, and a subpar performance.

  Procrastination usually leads to long cramming sessions. It is much better to work for many short periods of time than to spend the same amount of time in one long session, which is usually what happens when you procrastinate. Avoiding procrastination is perhaps the number one key to success in college—and beyond.

- *Take charge of your education.* Some people watch the world go by. In order to succeed in education—and in life—you must take an active part in the process. You must be an actor and not a viewer, part of the cast and not of the audience. Your education is *yours,* and only you are responsible for it.

  Don't fall into the trap of excusing a poor performance by saying that it was someone else's fault or due to circumstances. *You* are the one who suffers if your education is less than it might be. For example, if you miss a class because your roommate turned off the alarm clock, it is easy to tell yourself that it isn't your fault, that your roommate is to blame. While this may be true, it is *you* and not your roommate who must suffer the consequences of the missed class. Therefore you must take the active role and repair the damage by going to see the professor or by getting notes from others in the class.

  When you find yourself beginning to make an excuse for a missed opportunity, stop immediately, and figure out how you can get the opportunity back. Education is not passive, like watching TV; education is a *participatory* sport. Take charge of your education.

Specific Skills

Here we offer some suggestions to help you manage your studies and improve your mastery not only of physics, but of other subjects you are studying. You are probably already doing some of the things we will suggest, but we hope to present a few new ideas that will help you. Read over the following suggestions. There are far too many to implement immediately, so pick a few that seem right for you under each category and put them into action. After they have become habits, reread the section, pick a few more,

and apply them. Using these ideas may pay huge dividends—not just in college, but throughout your life. Learning does not stop at graduation, and the ability to learn fast will serve you well throughout life.

Mastering new skills requires some work at first and may demand that you break established habits. In the long run, though, the time you spend learning the new study skills presented here could save you far more time than you invest. More importantly, efficient study habits will result in higher grades because you will have increased your knowledge and understanding.

General Study Skills

- Develop the habit of studying on a daily basis. This is part of the "avoid procrastination" advice.
- Set aside specific times each day for study. Determine when you are most alert and use that time for study. Let your friends know that this is your study time and that you are not to be disturbed.
- Study for short periods and take frequent breaks, usually after an hour of study. Get up and move around. Do something completely different for a few minutes. This will help you stay alert and active.
- Have an area dedicated for study. It should include a well-lighted space with a desk and the study materials you need such as a dictionary, thesaurus, paper, pens and pencils, a calculator, and a computer if you have one.
- Study each subject every day, or at least the day of the class, to avoid cramming for tests. Develop the habit of reviewing lecture material from a class the same day. Some courses require more work than others, so adjust your schedule accordingly.
- Look up new terms whose meanings are unclear to you in the glossaries of your textbooks or in the dictionary. Glossaries are preferred because they give the particular definition that is appropriate in the subject you are studying. In this book, new terms are defined in colored boxes when they are first introduced. A complete glossary is included at the end of the book.
- Don't assume that because you use a word every day you know its definition. Often a term is used in a much more restricted way in science, and its common definition is probably useless in a scientific context.
- If the instructor (or bookstore) has made a student study guide or computer study aid available, use it, or at least, ask your instructor's advice about it.

Classes and Note Taking

- Before the lecture, read—or at least scan—the chapter the lecture will cover. This way you will be somewhat familiar with the concepts and can listen critically to what is being said rather than trying to write down everything.
- By learning the vocabulary of the discipline before the lecture, you can cut down on the amount you have to write—you won't have to write down a definition if you already know the word.
- Spend 5–10 minutes before each lecture reviewing the material you learned in the previous lecture. This will provide a context for the new material.
- Avoid missing classes. Try to sit near the front of the room, where there are fewer distractions and you can clearly see and hear the instructor.
- Develop a shorthand system of your own. Symbols such as = (equals), w/o (without), w (with), > (greater than), < (less than), ↑ (increases), and ↓ (decreases) can save you time. When you find that certain terms are repeated frequently, develop an abbreviation for them. Electric charge might become ec.
- Omit vowels and abbreviate words to decrease writing time. (That is, omt vwls t ↓ wrtng tme.) This takes practice, but will pay off.

- Don't take down every word the professor says, but be sure your notes contain the main points, the supporting information, and important terms.
- Learn the mannerisms of the professor. He or she will usually have some way of indicating what ideas are important. For example, he or she may repeat them or write them on the board.
- Check any unclear points in your notes with a classmate, look them up in the textbook, or consult your professor.
- If the professor permits, use a tape recorder. Do not use this to replace note taking, however, for the act of writing notes keeps you focused on the lecture. Use the tape to fill any gaps you find in your notes.
- Review your notes soon after the lecture while it is still fresh in your mind. It is best to recopy your notes, inserting appropriate ideas and clarifications from the textbook. If time does not permit you to do this, leave room as you take notes so that you can add material later.
- Ask questions in class. If you are unclear about a point, other people probably are also, and they will be grateful for your question. If you are shy about asking questions in class, go up after lecture or visit your professor during office hours. Remember, *you* must take charge of *your* education.

Getting the Most from What You Read

- Before reading a chapter, look over the chapter outline or skim through the chapter. This will tell you what the material is about and provide a pattern for your thinking as you read.
- Take notes in the margin of the book or on a separate sheet of paper. Underline or highlight key points, but do not fall into the habit of extensive highlighting. Mark paragraphs or parts of paragraphs that contain explanations that are important and difficult, so that you can find them easily when you review.
- Pay attention to tables, charts, and figures. Physics is a visual science, and the illustrations will help you to understand and remember what is being discussed in the text.
- Read slowly. Concepts later in the chapter usually build on those introduced earlier, so careful reading can help you avoid confusion later.
- Study the Concept Maps in this book. They serve as visual summaries of material in the text and are particularly good at displaying relationships between concepts.
- Carefully examine the logic involved in going from one step of an argument to another. Calculations of many quantities in physics depend on previous measurements, computations, and assumptions. Be sure you understand these steps. If you don't, ask your professor for an explanation.
- Go over the exercises in each chapter. In this book, do the Learning Checks first. These are the simplest exercises in the book and should be easy to answer. Move on to the end-of-chapter Questions and Problems. Many of the Problems are similar to worked Examples in the text, so you may want to go over them again. Write out your answers as if you were taking a test. Only when you see your answer in writing you will know if you understand the material.

Preparing for Tests

- Most important: Keep up with the professor day-to-day by reading any assignments and by reviewing your lecture notes. Don't depend upon cramming the night before the test. Instead, get plenty of rest that night.
- Find out how much of the test will come from lecture notes and how much from the text, and find out what type of test will be given.
- About a week before the test, start reviewing previous chapters and your lecture notes. Pay particular attention to how this material ties into later material. Try to see the big picture.

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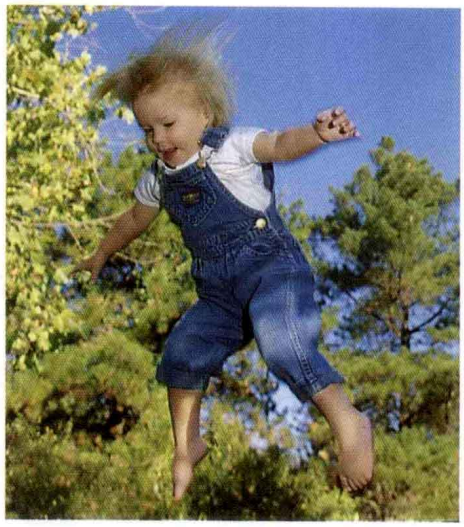

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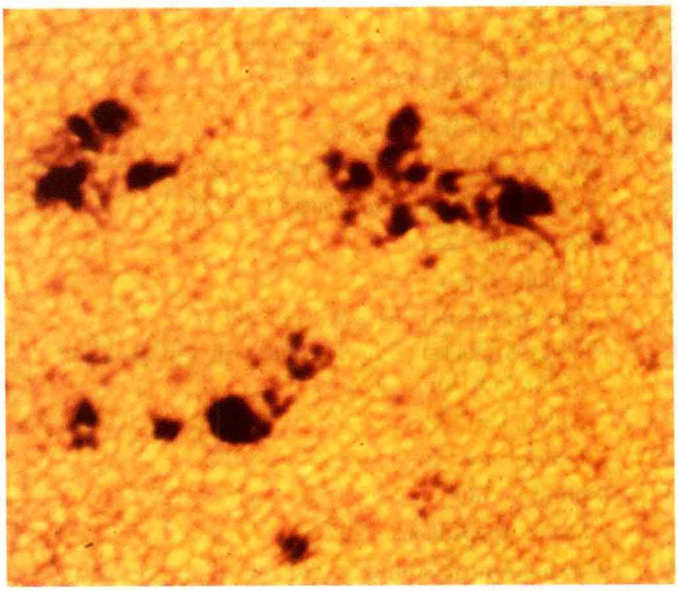

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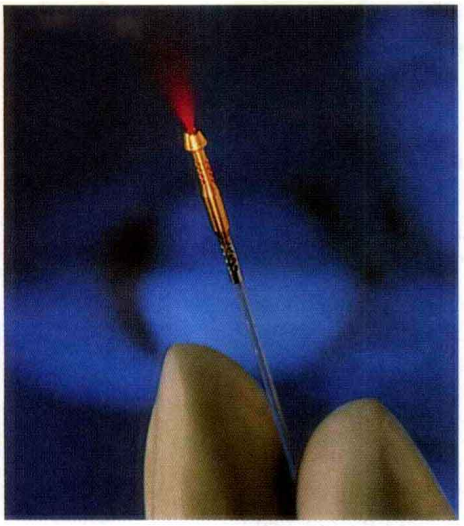

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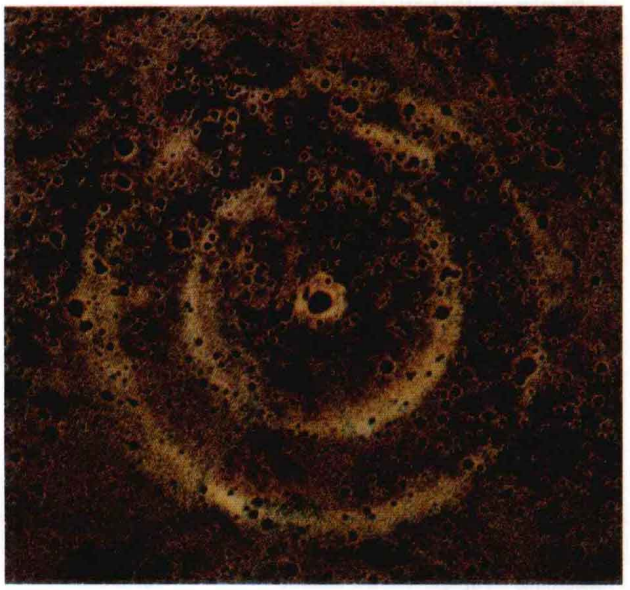

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