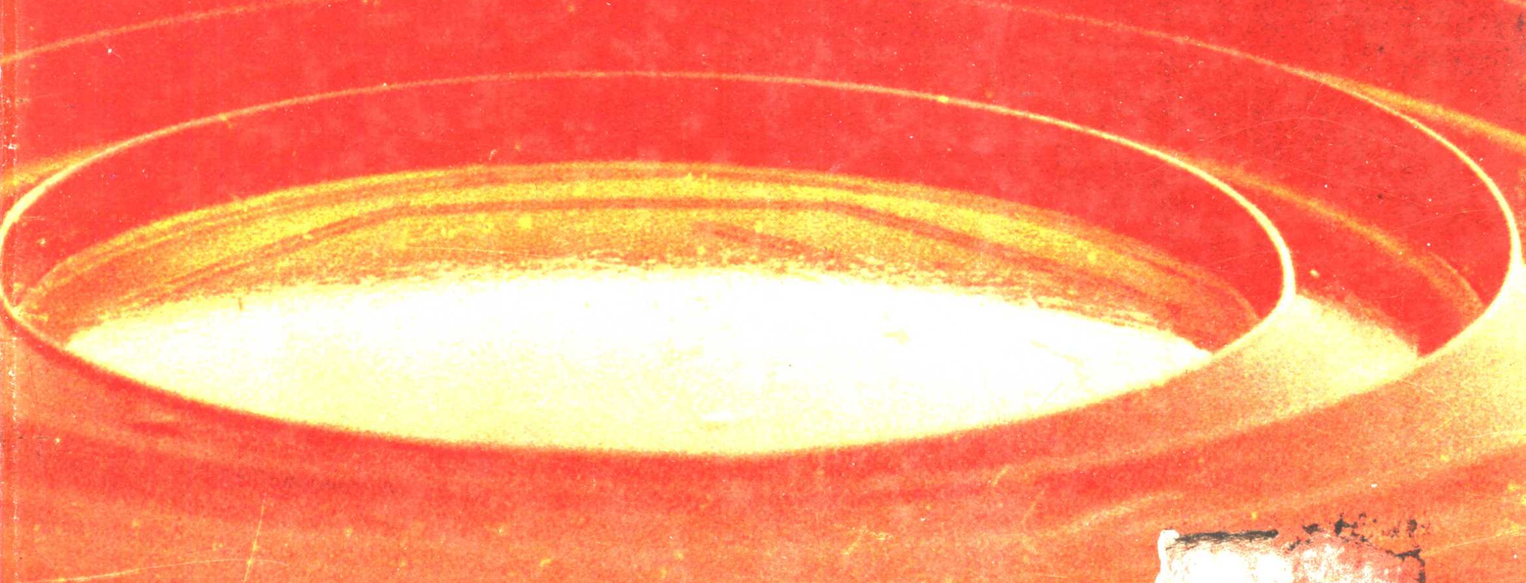
College Physics



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COLLEGE PHYSICS

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McGraw-Hill Book Company
New York St. Louis San Francisco Auckland Bogotá Hamburg
London Madrid Mexico Milan Montreal New Delhi
Panama Paris São Paulo Singapore Sydney Tokyo Toronto

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2 3 4 5 6 7 8 9 0 VNHVNH 8 9 4 3 2 1 0 9 8 7

ISBN 0-07-052142-5

This book was set in Berkeley Old Style by Progressive Typographers Inc. The editors were Irene Nunes, Karen S. Misler, and Steven Tenney; the production supervisor was Phil Galea; the design was done by Caliber Design Planning. The drawings were done by Felix Cooper. Von Hoffmann Press, Inc., was printer and binder.

Library of Congress Cataloging-in-Publication Data

Buckwalter, Gary L.
College physics.

Includes index.
1. Physics. I. Riban, David. M. II. Title.
QC21.2.B814 1987 530 86-20160
ISBN 0-07-052142-5

Preface

One of the distinctions of a course in college physics is that very few of the students taking it are doing so by choice. Physics is the base for much of modern science and technology, and a knowledge of it is required in many fields of study. It is usually the case, however, that students who major in the physical sciences and engineering begin by taking a physics course that is based on a knowledge of calculus. This leaves the student clientele for the physics course based on algebra and trigonometry — "college" physics — a captured audience that, once the course is finished, will likely not be seen again by the instructor or the physics department. This situation makes for poor feedback on the effectiveness of a textbook unless instructors are constantly trying to assess whether the presentation really works with the students. Much of the motivation for our writing this book grows from this type of assessment.

Physics is a difficult subject. There is no way to gloss over that fact, and any student wise enough to gather comments from other students who have taken the course will know that already. An ancient prince fascinated by mathematics despaired at the time it took to understand things. He was informed that "there is no royal road to geometry." Likewise, there is no way through physics without an honest effort. *Because the subject is quantitative and cumulative, you will need to do your best from the very start or else, in order to pass later tests, go back and relearn things after having already been tested on them.* This is not new or different, and you are not being discriminated against. All who have passed the course have "paid their dues" in intensive study and long sessions of solving problems.

There is no virtue in making something that is relatively simple appear harder than it is. There is a very considerable danger, however, in making something inherently complex look much simpler than it is. In writing this text, we were faithful to a simple set of ideas. First and foremost, *the physics had to be correct.* Nothing horrifies an instructor more than finding a section of a text that is just plain wrong. Should such error slip past the initial class, there is no telling what damage and unlearning might have to occur if the area is one in which a student will need to be knowledgeable later on. Of course, saying it correctly bears a penalty at times, but we have tried to work our way to the careful statement of the physics throughout the book. Normally, the introductory portion of a chapter explores phenomena in an intuitive way to allow the reader to develop a feeling for the area to be considered. Later, precise definitions are developed and used. Usually this approach is good for students but frustrating for instructors, more used to a direct mathematical plunge into the subject. Thus, for example, this book takes several pages and runs through many examples to get to the point of defining the important concept of work. Since instructors are well familiar with the applications and intuitively accept what the mathematical definition is stating, many might be happy with a cursory introduction to new concepts and a plunge into a derivation. You, the student, will benefit greatly if you patiently work through the introductory section to get to the real takeoff point for the chapter.

The second guiding principle in writing this text was that the book be *readable*. If a text is unreadable or hard to read, it usually isn't read. This tends to be a prescription for disaster for the student. Physics has great subtlety. Doing well frequently depends not only on what you know but also on whether you understand the subject. Many courses that you have had, even quite difficult ones, put a premium on memory. Physics may represent a novel task for you in that memory is not nearly so important as understanding is. In writing the text, we have been very careful to state clearly just why or when a particular idea is valid and may be used. Merely to know the idea may not be enough to apply it correctly on a test.

All physical laws have conditions under which they apply and limitations to their general applicability. The fewer the conditions, the more general the law. Normally, it is a great mistake to search for and use indiscriminately any equation that just possibly could be right because it involves the appropriate variables that are given in a problem.

A textbook is an organized guide to a subject that facilitates your learning. It should be clear, complete, and correct, but the textbook cannot learn for you. At best, it is a vehicle to optimize your ability to learn — to let you get the most understanding possible for the time expenditure you must make. Several devices have been used in the text to aid you in using the book.

Worked Examples

In each chapter, you will find many worked example problems. These are illustrations that show how to use new concepts in attacking problems like those found at the end of the chapter. We have tried to make the explanations complete and to show all the essential steps in the solution. Also, even though space in a book is always at a premium, we have selected some problems for examples that are at least as long and involved as anything found in the problem sets. Careful study of these examples can provide you with a good base for doing homework problems.

Problems

Well over 1200 multiple-part problems are presented at the end of the chapters. Throughout the writing of the text, we took a great deal of time to develop problems without reference to any text in print. That does not say that every one represents a new and unique problem not found in any other text, as authors have memories, too. It does imply, though, that each came from an attempt to use the chapter materials as they had been written as the source for the physics needed to work the problems. It will be little consolation to a student laboring over them, but many reviewers have specifically noted the problem sets as unique and a particularly strong feature of the text. The proof of the merit of these problems, however, is in how well they teach you physics. In every set, the physics of the chapter has been applied to some outside subject areas. Physics is physics no matter what the area of application. It is well to remember that the professionals in your own area of study feel that a knowledge of physics is important enough to require it of all the students with your major. Clearly, they believe it can be applied in your area of specialization.

The problems are divided into three types. Problem numbers printed in normal type indicate relatively easy, straightforward problems that should not present a great deal of difficulty to the average student. Problem numbers printed in **boldface type** indicate problems of a higher level of difficulty, usually involving more than the simple application of an idea freshly presented or more than routine mathematical manipulation. Problem numbers printed in color designate the most difficult problems in the sets. All physics problems may be hard, however, if you don't know what you're doing; most may be easy if you do. In any case, the levels grade continuously into each other. Thus, a problem marked less difficult in one chapter may well give more of a challenge than another marked more difficult in another chapter. Problems from areas that "click" for you might prove easy. On the other hand, those at the end of a chapter from which a fundamental idea really didn't enter your consciousness may give you trouble from the start. Each problem is an opportunity to gain in the ability to work with physics, and even the hardest problems in this book have been judged by the authors to be workable by a reasonable student trying hard to do well in this course.

The answers to the odd-numbered problems are provided at the back of the book. It becomes very rewarding to find that you have the right answer the first time you work a problem. If you don't have the right answer, the answers list allows you to find out promptly so that you can reexamine your approach. Although only the numerical answers with units are given, this is usually enough to show if you are on the right track or completely off the mark.

After gross content errors, there is probably nothing more distracting in a text than the presence of numerous erroneous solutions in the answers. Certainly nothing undermines student confidence faster than to find that the number she or he has been struggling for an hour to obtain is simply wrong. This goes beyond being distracting to become counterproductive with students, encouraging them to quit early when the going gets tough. It is also a familiar reason for instructors to drop a text from consideration for use, even if it has other meritorious points. Everything reasonable has been done to ensure that the answers presented in this book are correct. Each problem was worked completely and independently for the answers section by Dr. Dana Klinck of Hillsboro Community College, Tampa, Florida, and by Dr. Alvin Rusk of Southwest State University, Marshall, Minnesota. Their full solutions were then compared with those of the authors and merged by us to generate the answers. The final typed version was then rechecked against the originals to eliminate typographical errors. While no procedure is a complete guarantee that a text or its problem solutions will be error-free, everything reasonable has been done to minimize the probability of error.

One final note. Chapter 2 presents a long section on how to solve a physics problem. You may find this of help since problem solving will invariably occupy a great deal of your study time for this course. There is no way to bypass such practice and still do well in physics.

Minimum Learning Objectives

It is well to remember that, following the study of a chapter in this book, you will be expected to be able to do something as a result. At the end of each chapter, you will find a set of minimum learning objectives for the chapter. (These are at the end because you might not understand the vocabulary of the objectives before reading the chapter, but you are welcome to try.) The first objective gives the new terms you should be able to define and use after reading the chapter. Definitions in physics are expected to be precise, not vague — so practice. At the same time, not all definitions are printed in boldface in the text because some items do not lend themselves to a one-sentence definition. If you cannot give a crisp, clean definition of a term, reread the appropriate portion of the text. It is very important that you do achieve this first objective, however, because it will be difficult to work the problems if you don't really understand what the words mean. The later objectives in the list stipulate exactly what you should be able to do after mastering the material presented. Furthermore, each of the objectives stated is reflected in one or more of the problems of the following problems set.

Be warned again, however, that *physics is a cumulative subject*. It is completely appropriate that problems in a later chapter require you to know the content of an earlier chapter. This is one of the key reasons for you to determine to do as well as you possibly can from the very start of the course. Any deficiency you develop in earlier materials must be made up if you are to do well later. It really is much less painful in the long run not to allow a lack of understanding to develop in the first place.

Marginal Notes

Many times, to emphasize a particular point or to restate something in more intuitive terms, a marginal note is included alongside a discussion. Many of these notes are tips based on our experience in teaching this course for many years. We hope the suggestions in the notes are of help to you. Some try to clear up points that students overlook or get incorrect time after time even though the points are stated correctly in the text and even emphasized. We have avoided using an overabundance of these marginal comments to make sure they are noted when they are presented.

Appendices

In addition to the inside front cover, which contains frequently used constants and conversion factors, there are four appendices at the back of the book. These appendices contain information referenced less often but needed nonetheless. Some students will find it quite helpful to work through Appendix A, which reviews necessary mathematical operations and procedures. Students frequently find that their mathematical skills have become rusty if they haven't used them recently.

Study Guide

An accompanying study guide is available for the course, written by Dr. Marllin Simon of Auburn University. Dr. Simon began working from the earliest drafts of our manuscript to develop materials based directly on the text treatment of the subject. Many students will profit from the detailed practice a study guide can provide.

Acknowledgments

In his office, a very famous author keeps a painting that shows a turtle perched atop a wooden fence. This, he says, is to remind him that "if you see a turtle sitting on a fence post, you know it had some help getting there." Such a

painting would be especially appropriate for the authors/turtles of this textbook, and we wish to acknowledge the help, direct and indirect, we received during the book's development.

We have benefited from the comments of the large number of scholars who read and reviewed the manuscript at one or more of its various stages of completion. We found the advice and suggestions of the following to be quite useful and wish to express our sincere appreciation: Dr. John Paul Barach, Vanderbilt University; Dr. Bennet B. Brabson, Indiana University; Dr. Fred E. Domann, University of Wisconsin; Dr. David J. Ernst, Texas A & M University; Dr. Richard E. Garrett, University of Florida; Dr. Philip Hetland, Concordia College; Dr. Verner Jensen, University of Northern Iowa; Dr. Dana S. Klinck, Hillsborough Community College; Dr. David Markowitz, University of Connecticut; Dr. Konrad Mauersberger, University of Minnesota; Dr. Joseph L. McCauley Jr., University of Houston; Dr. Robert Merlino, University of Iowa; Dr. William Riley, Ohio State University; Dr. Marllin L. Simon, Auburn University; Dr. Charles W. Smith, University of Maine at Orono; Dr. Thor Stromberg, New Mexico State University; and Dr. Gordon Wiseman, University of Kansas.

Daniel G. Reiber, Professor Emeritus, Indiana University of Pennsylvania, read the entire manuscript in some of its earliest drafts. He provided many valuable recommendations for which we are most grateful.

Many people on the editorial, design, and production staffs of McGraw-Hill as well as several free-lancers have contributed to the final product. There is a danger in attempting to list all these people by name, in that some could be slighted by unintentional omissions. Thus we simply recognize the support of the entire College Division of McGraw-Hill Book Company. We do, however, extend a special thank you to our basic book editor, Irene Nunes, whose ability and dedication are well known but who, more than once, made the extra effort to snatch victory from the jaws of defeat, as it were.

We are deeply indebted to Mary Buckwalter, who prepared each of the many versions of the manuscript, correcting many errors and deciphering the nearly illegible handwritings of both authors in the process. Her efficiency and dedication all but eliminated one of our major concerns — manuscript preparation.

All the constructive criticism and other assistance we received combined to eliminate errors and provide a superior textbook. Thus the dearth of errors in this text is testimony to the quality of this assistance. Of course, any errors that remain are the sole responsibility of the authors.

Finally, we wish to express our fond appreciation to our wives, Mary Buckwalter and Kathleen Riban, who during this project provided the support and encouragement we could not obtain elsewhere. Further, they uncomplainingly endured the neglect that is the inevitable result of fully employed professors taking their discretionary time to produce this kind of textbook.

Gary L. Buckwalter
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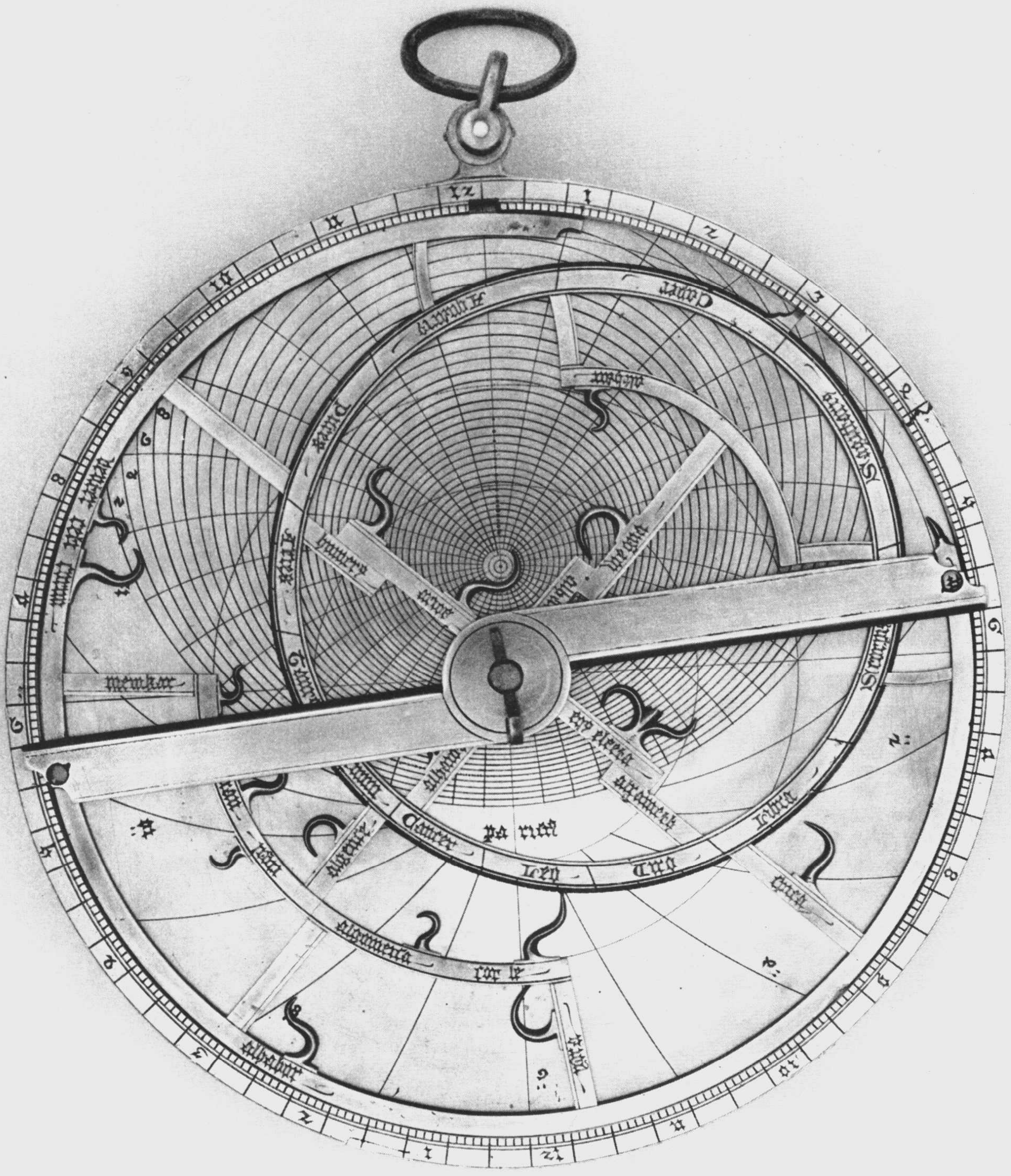

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1 Preliminaries and Definitions

1-1 Introduction

The typical student begins a first college physics course wondering, "Is there anything in this for me or is this just another hurdle which I have to get over?" Although some study physics because they are interested in the laws of nature, most students in this course are here because it is required of their majors. However, just knowing that experts in a student's chosen field have agreed that a knowledge of physics is an essential component of the student's education does not make the course more interesting or easier. In fact, many of those experts might agree that there is no way to make the study of physics easy. However, it is possible to make physics palatable — agreeable to the mind — so that the student, having conquered the principles, will feel deep satisfaction in having made the necessary effort.

In addition, there are so many interesting facets of physics that each of us can take delight in understanding some physical principle which explains some occurrence in our daily lives. Physical principles help explain the rocket, why a table tennis ball may curve, how a refrigerator works, and why so little power is required for a liquid-crystal display. These topics and hundreds more will be encountered in this text. First, however, we must learn the language.