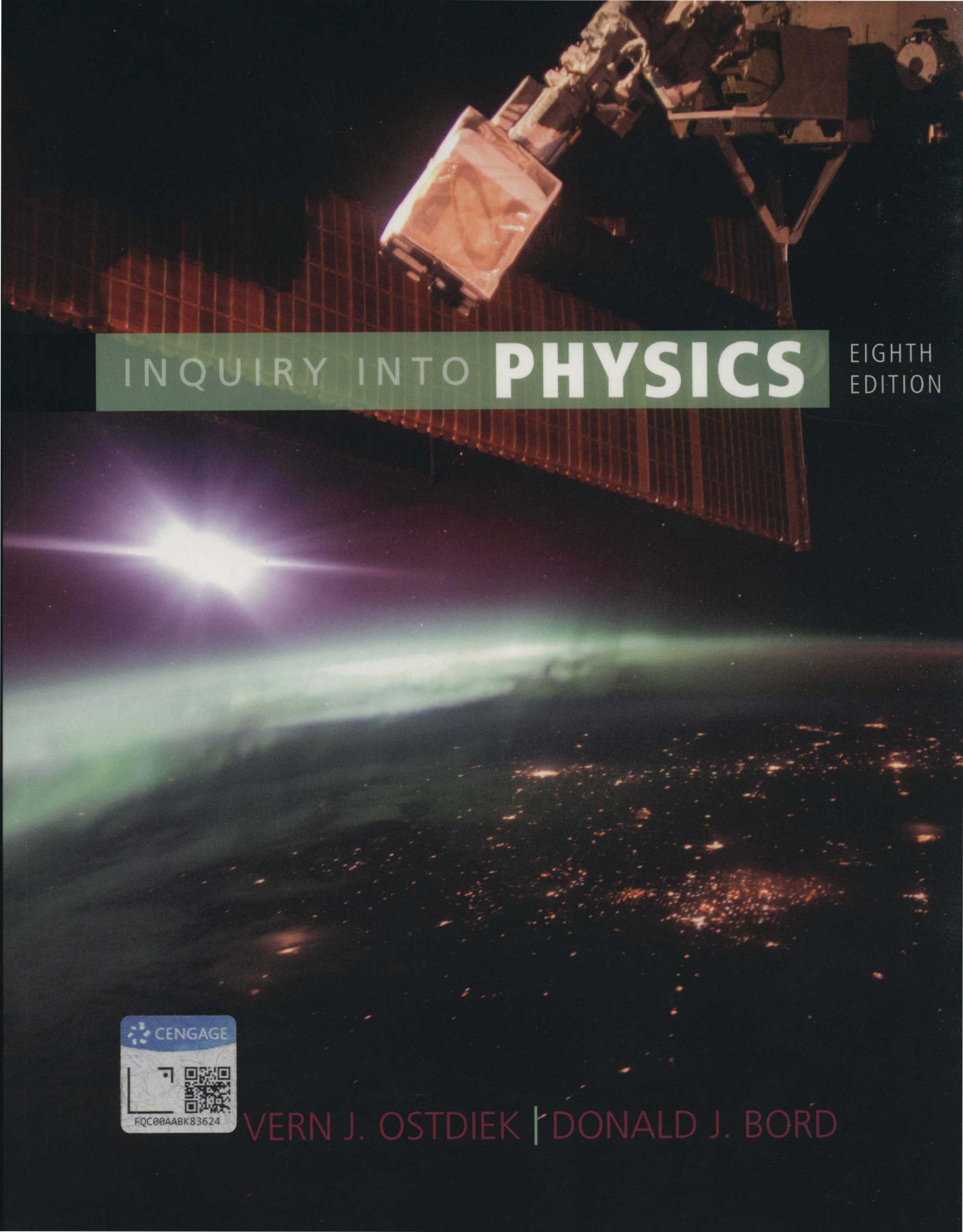




INQUIRY INTO **PHYSICS**

EIGHTH
EDITION



VERN J. OSTDIEK | DONALD J. BORD

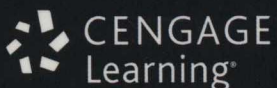
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Eighth Edition

INQUIRY INTO **PHYSICS**

VERN J. OSTDIEK | DONALD J. BORD

University of Michigan—Dearborn



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Vern J. Ostdiek, Donald J. Bord

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PHYSICS CONNECTIONS TO THE REAL WORLD

Okay, so you are ready to learn about physics. But what, you may ask, is it good for? These two pages show you one part of the answer to that question: physics helps you better understand what is going on around you and in the rest of the universe. Listed here are many of the applications of physics found in the text, along with the page(s) on which each appears. (Some references are to Problems or Challenge exercises that involve the application or device.)

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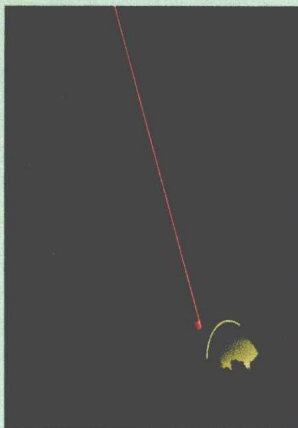
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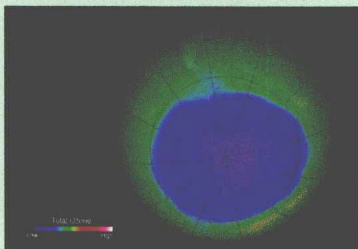
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Welcome to the eighth edition of *Inquiry Into Physics*. In this edition, the emphasis on the inquiry approach to learning physics is continued. Readers are encouraged to try things, to discover relationships between physical quantities on their own, and to look for answers in the world around them rather than seek them only in books or on the Internet. This book should not be treated as an answer key to the nature of physical phenomena (although it does offer many explanations of how things work), but as an extended invitation to examine things for yourself in a direct, hands-on fashion and to be daring and experiment on the various systems and structures that surround you. As you progress from topic to topic, give free rein to the innate curiosity that we all possess from birth, and don't be afraid to ask questions about the things you experience daily. Keep in mind that learning is a more exciting, complete, lasting, and enjoyable process when you are fully engaged in it and not merely a passive recipient of facts and statistics offered by your instructors, this text, and other print or electronic sources. Get in the game—of physics!

Our Intended Audience

This book is designed primarily for students who are taking an introductory physics course, perhaps for the first time, to satisfy collegiate requirements or who wish to satisfy their curiosity and thirst for understanding about the structure and range of interactions that characterize our physical universe. It offers a broad survey of the fundamental definitions, laws, and principles of the discipline of physics, as well as a large sampling of applications of these concepts in virtually every aspect of human experience. *Inquiry Into Physics* provides a first look into the things that comprise our universe, from the smallest subatomic particles to the largest galaxies, as well as the interactions that can occur between those things, from energy-releasing reactions among atomic nuclei to gut-wrenching collisions between automobiles, to gravitational interactions among stars and whole galaxies that result in catastrophic disruptions over time scales that dwarf modern humankind's 200,000-year history on Earth. In ways both large and small, physics principles and applications touch our lives literally from moment to moment: in the pumping action of the heart and the flow of blood in our arteries and veins, in the electrical impulses that enervate our muscles and organs, and in the processes that drive our senses of sight and sound and permit us to see and hear the goings-on in the world around us.

Physics also satisfies our intellectual curiosity by revealing Nature's secrets about things both mundane and exotic. Discoveries in physics, like the processes

of nuclear fission and fusion, have shaped the political landscape of the world and are likely to continue to do so well into the future. A look back at the women and men who made many of these important discoveries connects us with our past and gives us deeper insight into the pathways that can lead to scientific understanding. These aspects and others are blended throughout the text in an effort to provide you with a sense of the unity both within the discipline of physics and between the subject and its human practitioners. The tools we use to present these facets of physics are basic ones: the written word; visualizations and models in the form of hundreds of photos, diagrams, and graphs; and simple mathematics to show how the conceptual side of physics is inextricably woven together with its quantitative side. By these means, we hope that you will complete your introductory study of physics, having achieved a greater appreciation not only for what we know about the physical universe, but also how we have come to know it.

What's New?

Each chapter has been thoroughly reviewed, and many sections have been rewritten to improve the clarity and accuracy of the prose. The text has been updated and in some cases expanded to reflect the latest scientific discoveries and achievements in the fields of physics and astronomy, and new material has been added to reflect current affairs and increasingly popular applications of physics principles in 21st-century life. Each major chapter section has been divided into subsections to better call out the content and organization of the main topic for students and to permit instructors to more finely tune reading assignments to their needs and preferences. The art program has been substantially improved throughout the book to offer more contemporary and relevant photos and figures to illustrate the connections between fundamental physical concepts and the modern world. In particular, in figures containing vectors, the arrows have been made bolder and the color scheme used to identify each vector expanded and made more internally consistent to aid in recognizing and relating such quantities. In addition, the format for the worked examples has been modified to better delineate the questions and the solutions, and the answers are now shaded to give them greater prominence.

The long-standing "Physics Potpourri" series has been reconceptualized and in some cases reorganized as a suite of "Applications" essays, focusing attention on ways that physics principles have been and continue to be applied to change—and hopefully enhance—our world. These text elements now also include one or two review questions to support student engagement. An expanded set of end-of-chapter (EOC) exercises,

including more than 80 new questions and problems, has been provided, and the “explore-it-yourself” application boxes have been retitled “Physics to Go” to better emphasize the “take it with you” exploratory aspects of these features. The former “Physics Family Album” vignettes have been shortened in many cases and renamed “Profiles in Physics” to emphasize their focus on key personalities in the development of the discipline; like the “Applications” articles, the “Profiles” sections now contain review questions to better promote their use as important pedagogical elements of the book.

Some specific changes on a chapter-by-chapter basis include the following:

Prologue Updated *Application* highlighting the commercial aspects of the metric system and the new emphasis on units defined in terms of fundamental constants. Fifty percent of the art is new.

Chapter 1. More than a dozen new photos and line drawings are included. Three new EOC exercises and a new example have been added.

Chapter 2. Updated discussion of the *New Horizons* mission to Pluto, plus a new *Application* feature on *Chaos*. Five new EOC exercises and three new worked examples have been added.

Chapter 3. More than a dozen new figures have been introduced. An updated *Important Equations* section now appears to reflect new material on elastic energy and torque. Eight new EOC exercises and three new worked examples have been introduced.

Chapter 4. More than a dozen new figures have been included. The updated feature on element nomenclature includes the latest discoveries and naming conventions for the heaviest elements. New material on hydraulics and fluid flow has been introduced. Thirteen new EOC exercises and two new worked examples have been added.

Chapter 5. Expanded discussion of the ideal gas law. Expanded treatment of entropy and energy quality. Thirteen new EOC exercises and three new worked examples now appear.

Chapter 6. Twelve new figures and new material on the Hubble relation have been provided. Five new EOC exercises have been included.

Chapter 7. Revised and updated chapter opener on iProducts. More than a dozen new photos and refreshed line drawings. Updated information for Tables 7.1 and 7.2, plus additional material on superconducting power grid projects in the United States and Europe. Three new EOC exercises have been added.

Chapter 8. Nearly a dozen new or updated figures. Additional discussion of superconducting electromagnets and new information about the greenhouse

effect and environmental evidence for climate change are presented. Two new EOC ranking exercises have been added.

Chapter 9. Explicit inclusion of mathematical treatment of double slit interference with a new worked example. Updated discussion of the Hubble Space Telescope focusing on instrumentation missions. Five new EOC exercises have been added.

Chapter 10. Nearly a dozen new or enhanced figures have been included.

Chapter 11. Updated discussion of clean-up work at the Fukushima Daiichi reactor site in Japan five years after the destructive earthquake and tsunami struck the plant. New material on radiation therapies for brain tumors using a gamma knife. Four new EOC exercises have been added.

Chapter 12. This chapter has been completely revised and merged with the former Epilogue on cosmology to produce a fresh and unified treatment of relativity, particle physics, and cosmology. A new section on general relativity with two new worked examples and a treatment of the LIGO discovery of gravitational waves now follows the opening discussion of special relativity. The subsequent three sections addressing particle physics and the Standard Model have been streamlined, while including material on the discovery of the Higgs boson and updates to the tabulated data for elementary particles and the Standard Model. Nearly a dozen new figures have been provided, and the *Summary* and *Important Equations* sections have been altered to reflect the new information. A new Mapping It Out! exercise dealing with the concepts and predictions of general relativity has been inserted, and 24 new EOC exercises have been added covering the new topics.

What’s the Plan?

The traditional organization of topics followed in many introductory physics courses has been retained for this new edition. Once again, we have eschewed the use of shorter, more narrowly focused chapters and have continued with longer ones that offer the opportunity to present the overarching conceptual unity and continuity of the broad subdisciplines that make up our subject (kinematics and dynamics, energy, thermodynamics, optics, atomic and nuclear physics, etc.). Each of the 12 numbered chapters is built around the following common features:

Chapter Introductions. Opening each chapter, these examples of physics as it plays out in everyday life serve to motivate the reader to immediately engage with the material by showing how a common device or issue of current interest and importance connects to the concepts developed in the chapter.

Examples. Worked exercises that illustrate the roles of physics principles and simple mathematics in real-world situations are regularly presented as models for problem solving.

Physics to Go activities. These hands-on experiments and exercises give students the chance to see and do physics without the need for specialized equipment or highly sophisticated techniques. These investigations are generally strategically placed before the relevant text discussion, inviting the reader to directly experience the upcoming concepts and to begin to formulate their own understanding of them.

Learning Checks. Simple self-quizzes, designed to test the reader's basic comprehension of the material on a section-by-section basis, are included in each chapter.

Physics Applications essays. These self-contained features explore selected topics drawn from astronomy, the history of science, engineering, biophysics, environmental physics and other areas. These essays are provided to deepen and enrich the student's understanding of physics and especially its applications.

Concept Maps. Based on principles developed from educational research, these visual displays offer an alternative representation or organization of the relationships between important chapter concepts.

Profiles in Physics. The final content section of each chapter presents a look at the historical development and the human side of physics by describing aspects of the lives and work of some of the key men and women responsible for the discovery and expression of the laws and concepts presented in the chapter.

Summary. Each chapter summary is a brief, bulleted review of the key points in the chapter and a short, helpful list of the major concepts for students when preparing for tests and quizzes.

Important Equations. An annotated list of the equations included or developed in the chapter is presented for quick reference when problem solving.

Mapping It Out! These exercises, many intended for group collaboration, are included to help students use concept-mapping techniques to organize, unify, and improve their understanding of important concepts and relationships introduced in each chapter.

Questions. These end-of-chapter queries check students' basic understanding of the material and their ability to extend that understanding to new and different situations. A special icon (■) is used to distinguish the first type of question from the second for ease of identification and selection.

Problems. These end-of-chapter exercises offer students opportunities to hone their critical thinking skills using logic and simple mathematics to solve problems based on realistic applications of the physics developed in each chapter.

Challenges. More advanced questions and problems designed to test a reader's mastery of the material at a deeper level are included at the close of each chapter for the benefit of highly motivated students. Many of these exercises can be used as starting points for small group or whole class discussions.

Conveniently located in the appendices and front and back endsheets of the print version of this book are several additional resources that are helpful in problem solving or in gaining further appreciation of the scope of physics applications in the 21st century. These include:

- **Selected Applications** of physics concepts and principles ("Physics Connections to the Real World")
- **Tables of Conversion Factors** and other information (for example, tables of metric prefixes, physical constants, and other often-used data)
- **Periodic Table of the Elements**
- **Winners of the Nobel Prize in Physics**
- **Math Review**
- **Answers** to the odd-numbered Problems and to many of the Challenges and the Physics to Go activities (where appropriate).

There is more than enough material in the text than can usually be covered in a typical one-semester course. However, about 30 of the more specialized sections may be omitted with minimal impact on the later topics. Specifically, these include the **Applications** features and the **Profiles in Physics** segments and Sections 2.8, 3.8, 5.6, 5.7, 6.4, 6.5, 6.6, 8.4, 8.7, 9.5, 9.7, 10.7, 10.8, and 12.1–12.6.

What Else Is There?

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Instructor Companion Site for Ostdiek & Bord *Inquiry Into Physics*, 8th edition

Everything you need for your course in one place! This collection of book-specific lecture and class tools is available online via www.cengage.com/login. Access and download PowerPoint presentations, images, the Instructor's Manual, videos, and more.

Each chapter of the **Instructor's Manual** by Thomas E. Sieland of Embry-Riddle Aeronautical University provides the following:

- Chapter outline
- Chapter overview
- Learning objectives
- Teaching suggestions and lecture hints
- Common misconceptions and how to counter them
- "Consider This" (additional tips and suggested resources)
- Answers to "Mapping It Out!"
- Answers to Questions
- Answers to even-numbered Problems
- Answers and brief solutions to Challenges

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Who's Responsible?

The production of this newest edition of *Inquiry Into Physics* involved the collaboration of many talented professionals at Cengage Learning. First and foremost, sincere thanks goes to Susan Dust Pashos, Senior Content Developer, for her steadfast support, keen eye, physics savvy, and deep understanding of what's possible and what's not in the publishing business. Without her wise advice, careful review, and effective advocacy, it is doubtful that this project would have come to fruition in as timely and successful manner as it has. Thanks are also due to Rebecca Berardy Schwartz, our Product Manager, whose confidence in this project and careful assembly of a team of consummate professionals within the Cengage Learning organization have produced what is arguably the best and most attractive edition of the book yet. Tanya Nigh, Content Project Manager, provided able and timely advisement and intervention on in-house production matters to resolve problems and maintain project momentum. The efforts of Michael Jacobs, Content Developer, to adapt content for the Learning Path in MindTap® for this edition of *Inquiry* are gratefully acknowledged, as are the contributions of Christine Myaskovsky, Intellectual Property Analyst, whose skill and perseverance in securing permissions for many critical images were unparalleled. The art program for this eighth edition has been updated and improved to an extent not seen since the first edition in 1985, and much of the credit for this transformation goes to Cate Barr, Senior Art Director, and Bruce Bond, Executive Director for Design, who, among other contributions, guided the thorough-going program of vector enhancements that are visible on practically every page of the book. Hats off to Cate as well for locating the exquisite cover image for this edition, which continues *Inquiry's* tradition of using striking images from Nature to call out the many ways in which physical principles are on display around us.

Kudos also go out to the vendors and contractors who have provided special services throughout the production of the book including Nitesh Sharma, project manager at our publishing and printing partner, Macmillan Publishing Solutions, in India, and Justin Karr and Susan Ordway who were instrumental in directing the XML coding for Mindtap®.

A deep debt of gratitude and appreciation is owed to Dr. Tom Sieland of Embry-Riddle Aeronautical University who once again, with skill and precision, developed the Instructor's Manual for the eighth edition of *Inquiry*. Tom's extensive experience as a physics teacher and his long-time classroom use of this book combine to infuse the Instructor's Manual with helpful pedagogical advice, accurate and authoritative solutions, and an extensive set of teaching suggestions and lecture hints specially matched to the book, thus making this ancillary a valuable resource for practitioners both new and more seasoned.

Thanks are also due to the many instructors and students who have used *Inquiry Into Physics* since its first appearance in 1985. Your advice, encouragement, and suggestions for improvement have been instrumental in keeping the book faithful to its original philosophy and purposes, up to date with regard to important developments in the field, and clear and accurate in its exposition. For this edition, a special expression of gratitude is owed to Dr. Vitaly Kresin at the University of Southern California and Dr. Brian Utter of Bucknell University

for their evaluation of an early draft of the new Chapter 12; their suggestions for improvement have been instrumental in yielding a more coherently organized and vibrantly expressed presentation of relativity and high-energy physics than was initially presented.

I sincerely thank all of you and hope you enjoy this latest edition of *Inquiry Into Physics*.

Don Bord
September 2016

Dedication

This book is lovingly dedicated to my wife, Cheryl, who, through seven editions and nearly 30 years, has unstintingly and with great good humor offered me her support, encouragement, loyalty, advice, and foremost, her love, without which this text and so many of my other personal and professional achievements would never have been possible.

Thank you, C.

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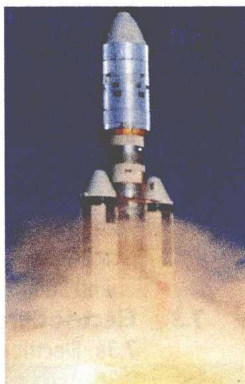
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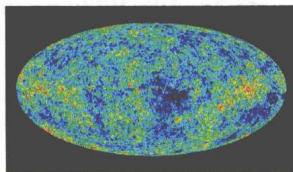
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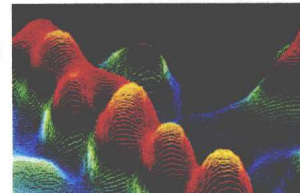
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