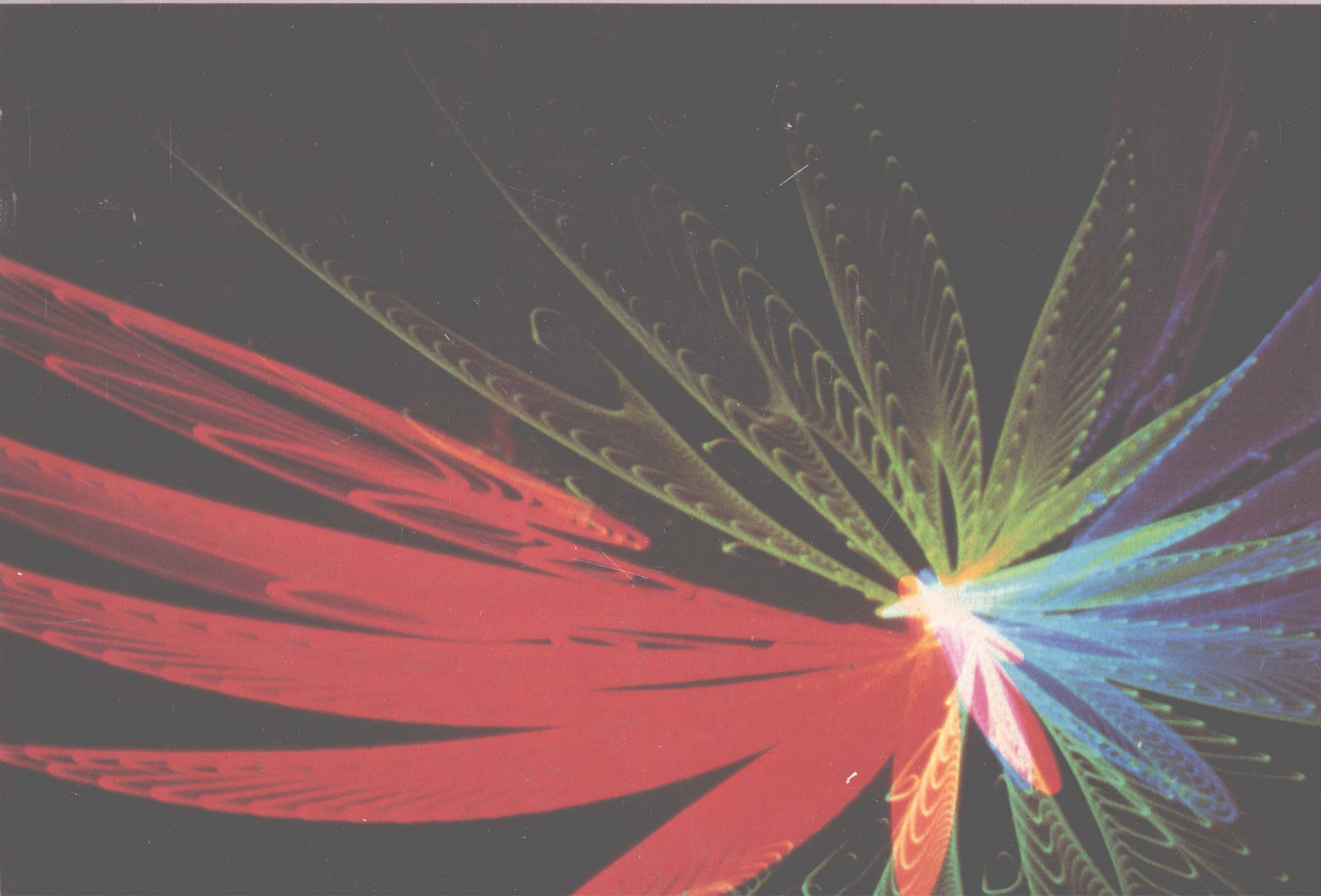
Second Edition

PHYSICS AND THE PHYSICAL PERSPECTIVE

HOOPER AND GWYNNE



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Preface

Physics and the Physical Perspective, second edition, is a textbook primarily for students who require a familiarity with but not an exhaustive knowledge of the science of physics: those who need the basics of physics for careers in medicine, dentistry, the biological sciences, agriculture, architecture, geology, oceanography, law, business, or as a general understanding of the physical world. Elementary physics texts and courses are often classified by the level of mathematics employed; this is a *noncalculus* text in which high school algebra is used extensively and trigonometry is used as necessary to provide insights and better understanding of the principles of physics. Because many students tend to have problems with the mathematics in this course, reviews of mathematical concepts are included where they are first used. In addition, Appendix A presents a detailed overview of mathematical concepts. Throughout the book, applications of a non-engineering nature should help students see the relevance of physics to their career goals.

Physics and the Physical Perspective, second edition, brings a new approach to teaching the subject at this level. The experience of a physics professor, who has taught this course for more than fifteen years at three very different universities, and the skills of a science writer trained in physical science have been combined to produce a text that is lively, readable, and informative for students while maintaining the intellectual integrity of the course. In addition, this edition benefitted greatly from the intense review of Mario Iona, professor of physics at the University of Denver and author of the "Would You Believe?" column concerned with textbook accuracy for *The Physics Teacher.* Mario contributed valuable suggestions for the text's revision. In addition, he reviewed substantial portions of the second edition text material during the first proof stages. Iona's critical comments increased greatly the clarity and exactness of the text.

Suggestions from first edition users were incorporated in expanding one or two sections of many chapters and clarifying a number of statements and problems. In addition, the comments from this extensive survey were used in restructuring the second edition. For example, based upon user comments, Chapter 2, Motion, was shortened by delaying a discussion of circular motion until Chapter 4, Universal Gravitation, where the circular motion and centripetal force are necessary applications to planetary motion. Power is introduced in Chapter 5, Energy, and is discussed again in several later chapters. A discussion of simple machines is introduced as a Special Topic in Chapter 5.

In Chapter 9, Fluids under Pressure, the presentation of topics was altered from the first edition so that viscous flow is now the last topic introduced. Thermodynamics was moved from Chapter 10, Thermal Energy and Thermal Properties of Matter, to the end of Chapter 11, Ideal Gases, and Thermodynamics, enabling simple examples of thermodynamics to be based upon the ideal gas law. The discussion of entropy was expanded. A Special Topic on home insulation, which introduces the R-factor and degree days, was added to Chapter 10. In Chapter 12 the discussion of simple harmonic motion (Section 12.2) was expanded to make it more complete.

Chapter 17 was completely reorganized and rewritten to include new material on ac circuits and ac power, along with material from the first edition's Chapter 25 on capacitance, inductance, diodes, and transistors. Chapter 17 ends with an introduction to electromagnetic waves via an elementary discussion of Maxwell's equations. The discussion of polarization formerly in Chapter 17 is now in Chapter 18, Section 18.5, after a discussion of the wave properties of light.

The Instructors Guide includes several suggestions for adapting the text to various academic-year calendars. Brief comments on the highlights of each chapter are presented to help instructors use the text in their courses. Suggestions for assignments, including lecture demonstrations and laboratory experiments, are also included, along with sample exam questions (some multiple choice) and answers to the even-numbered problems.

We use several features to brighten up what otherwise would be dry textual material. One element is the *narrative style* throughout the book, making each chapter a cohesive and complete story in itself. Each *chapter* is *outlined* on its opening page; unlike the first edition, the chapter contents now are contained within one page for concise reference.

At least two *Short Subjects* are interspersed throughout most chapters. These subjects are essentially "asides" to the text presentation. Although the subjects are not required reading–students can receive all the information they need from each chapter by concentrating solely on the basic text–they provide material that both interests the students and breaks up the text, making the going just a little easier. By showing how physics abuts the real world, the descriptive Short Subjects complement the text, ranging from 200 to 1000 words and including such topics as the history of the metric system, flywheels, holography, and biographies of Newton, Einstein, and Boyle.

There is a descriptive *Special Topic* at the end of each chapter. The Special Topics, from 1000 to 1500 words in length, treat, in greater depth, a subject of interest that is related to points discussed within chapters. Timely subjects the Special Topics cover include "The Urge to Unify," a discussion of a search for a unified field theory, "Producing Energy for the People," "Bone As a Building Material," and "Holding Down Those Heating Bills."

Within each chapter there are several other elements that serve both pedagogical and motivational purposes; these elements include definitions in **boldface,** important statements highlighted in color and placed in the margin, and important marginal notes and reminders. Each chapter contains many worked-out illustrative examples that clearly indicate techniques for setting up and solving typical problems. End-of-chapter material includes, besides a Special Topic, a summary, questions, and numerous problems. The extensive sets of problems are grouped by subject matter; within each group problems are graded from least to more difficult as the number of the problem increases. The appendixes are useful tables of physical constants, conversion factors, trigonometric tables, and, as mentioned, an extensive math review. Answers to all odd-numbered problems are at the end of the text. The answers were reviewed thoroughly by both authors, Mario Iona, and independent physicists.

As in the first edition, we use the mks system of units throughout the text, to attempt to minimize any confusion about units. The SI abbreviations are introduced at their first occurrence and thereafter used in the book. However, because the cgs and British systems are still used by many people, including scientists and engineers, we introduce them early in the book and use them occasionally in examples and problems.

Henry O. Hooper
Peter Gwynne

Useful Information

60 mi/h = 88 ft/s
1 mi = 1.61 km
1 kg weighs 9.8 N at earth's surface
1-lb weight has mass of 0.453 6 kg
2.2 lb of weight has mass of 1 kg
1 cal = 4.184 J, 1 kcal = 4184 J
1 eV = 1.602×10^{-19} J
1 atm = 76.0 cmHg = 1.01×10^5 N/m^2 = 14.7 lb/in.^{2}
931.5 MeV = 1 u $\times$ c^2 (speed of light)
1 u = 1.66×10^{-27} kg

2π rad = 1 r = 360^0
Area of circle = πR^2
Circumference of circle = $2\pi R$
Volume of sphere = $\frac{4}{3}\pi R^3$
$\pi = 3.14 = \frac{22}{7}$; $\sqrt{2} = 1.41$; $\sqrt{3} = 1.73$
$\sin 0^0 = \cos 90^0 = 0$
$\sin 90^0 = \cos 0^0 = 1$
$\sin 30^0 = \cos 60^0 = \frac{1}{2}$
$\sin 60^0 = \cos 30 = 0.866 = \sqrt{3}/2$
$\sin 45^0 = \cos 45^0 = 0.707 = 1/\sqrt{2}$

Physical Constants

Speed of light $c = 2.997\,9 \times 10^8$ m/s
Planck's constant $h = 6.625 \times 10^{-34}$ J · s
Charge on electron $e = 1.602 \times 10^{-19}$ C
Rest mass of electron $m_e = 9.11 \times 10^{-31}$ kg
Rest mass of proton $m_p = 1.67 \times 10^{-27}$ kg
Electric constant $k = 8.98 \times 10^9$ N · m^2/C^2
Universal gravitation constant $G = 6.673 \times 10^{-11}$ N · m^2/kg^2
Acceleration due to gravity $g = 32.2$ ft/s^2 = 9.8 m/s^2 at earth's surface

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3 Forces 55

4 Universal Gravitation 89

5 Energy 123

10 Thermal Energy and Thermal Properties of Matter 264

11 Ideal Gases, and Thermodynamics 295

12 Making Waves 330

17 Alternating Current and Electromagnetic Waves 516

18 The Nature of Light 552

19 Geometrical Optics 589

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1 The Nature of Physics

What is physics and why is it so important? Scientists have long tended to justify their pursuit of knowledge in an expression similar to that used by the British climber George Mallory to explain why he tried to conquer Mount Everest: "Because it's there." Certainly few physicists, or other scientists for that matter, start out on their avocation with anything but a desire to add to humanity's fund of knowledge, however abstruse their contribution may appear to the average person in the street, to scientists in other fields, and even to their colleagues in the next office. But the past half-decade has seen the emergence of articulate critics who argue that science in general, and often physics in particular, has caused more harm than good by creating nuclear bombs, nuclear power plants, aerosol sprays, vehicles that emit pollutants, and other devices that, in the critics' view, are harming our environment. These critics all too often confuse science—the pursuit of new knowledge—with technology—the application of that knowledge. The message is clear: in this age of skepticism, since scientific research is largely funded by taxpayers through government grants, scientists must justify their existence in more concrete terms than the mysterious interest their fields of research hold for them personally.

For physicists, an important part of this type of justification lies in the basic nature of their subject. Physics is truly a fundamental science, encompassing a range of subject matter from atoms to galaxies and even beyond, into the miniature world of subatomic particles and the unimaginably large arena of the nature of the universe. The first people who rationally could be called scientists were the priests and sages of ancient Babylon, Egypt, and China, who plotted the movements of the stars and planets through the heavens by using the evidence of their naked eyes. The man who was first to use what we regard today as the modern scientific method of moving from observation to theory to prediction to confirmation was also a physicist—a former medical student named Galileo Galilei, whose unstinting support around the turn of the seventeenth century of the theory that the earth orbits around the sun forced an intellectual struggle with the Roman Catholic Church which echoed throughout the civilized world.

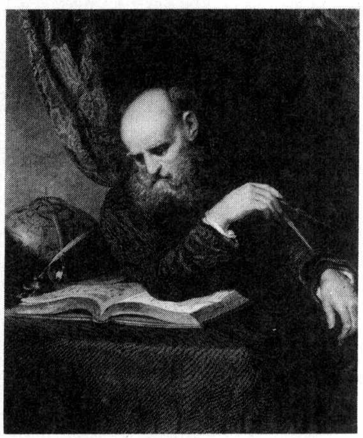

Figure 1.1 Galileo: source of an intellectual struggle. (*Culver*)

Less than 50 years (yr) after Galileo died, another physicist, Isaac Newton, reached what has been called "the greatest generalization achieved by the human mind" in his elegant yet simple laws of motion and the law of universal gravitation: the law that describes how the world goes round. Closer to our time, no scientist has ever achieved as much public adulation as physicist Albert Einstein, whose theory of