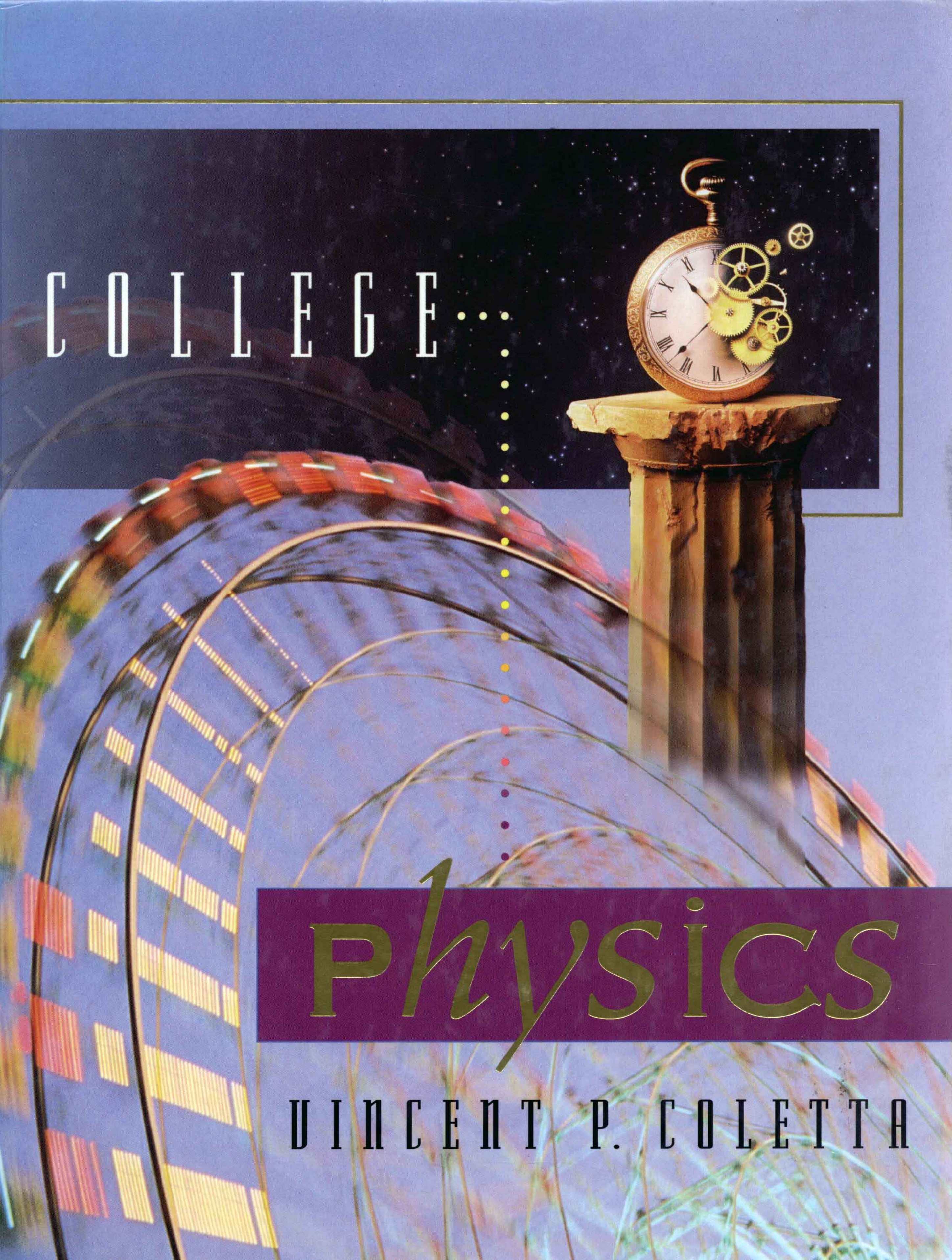
COLLEGE
physics
VINCENT P. COLETTA

# COLLEGE PHYSICS

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with illustrations

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# Unit Conversions

## Length

1 in = 2.54 cm
1 cm = 0.394 in
1 ft = 30.5 cm
1 m = 3.28 ft
1 mi = 5280 ft = 1.61 km
1 km = 0.621 mi
1 Å = $10^{-10}$ m = 10 nm
1 LY = $9.46 \times 10^{15}$ m

## Volume

1 L = $10^3$ $cm^3$ = $10^{-3}$ $m^3$
1 $ft^3$ = 0.0283 $m^3$
1 $m^3$ = $10^3$ L = 264 gal

## Time

1 day = 24 h = $1.44 \times 10^3$ min
= $8.64 \times 10^4$ s
1 year = $365\frac{1}{4}$d = $3.156 \times 10^7$ s

## Speed

1 mi/h = 1.47 ft/s = 1.61 km/h
= 0.447 m/s
1 km/h = 0.278 m/s = 0.621 mi/h
= 0.911 ft/s

## Angle

1 rad = 57.30°
1° = 0.01745 rad

## Mass

1 atomic mass unit (u) = $1.6605 \times 10^{-27}$ kg
1 kg = $10^3$ g
(1 kg weighs 2.20 lb where g = 9.80 $m/s^2$)

## Force

1 lb = 4.45 N
1 N = $10^5$ dyne = 0.225 lb

## Pressure

1 Pa = 1 $N/m^2$ = $1.45 \times 10^{-4}$ $lb/in^2$
1 $lb/in^2$ = $6.90 \times 10^3$ Pa
1 atm = $1.01 \times 10^5$ Pa = 14.7 $lb/in^2$
= 760 torr

## Energy

1 J = 0.738 ft-lb
1 ft-lb = 1.36 J
1 kcal = 4186 J
1 Btu = 1055 J
1 kWh = $3.60 \times 10^6$ J
1 eV = $1.602 \times 10^{-19}$ J

## Power

1 W = 0.738 ft-lb/s = $1.34 \times 10^{-3}$ hp
1 hp = 550 ft-lb/s = 746 W

# SI Derived Units

| Quantity | Unit | Abbrev. | Equivalent Units |
|---|---|---|---|
| Force | newton | N | $kg \cdot m/s^2$ |
| Pressure | pascal | Pa | $N/m^2$ |
| Energy | joule | J | $N \cdot m$ |
| Power | watt | W | J/s |
| Frequency | hertz | Hz | $s^{-1}$ |
| Electric charge | coulomb | C | $A \cdot s$ |
| Electric potential | volt | V | J/C |
| Electric resistance | ohm | Ω | V/A |
| Capacitance | farad | F | C/V |
| Magnetic Field | tesla | T | $N/A \cdot m$ |
| Activity | becquerel | Bq | $s^{-1}$ |
| Absorbed dose | gray | Gy | J/kg |

# SI Prefixes

| Factor | Prefix | Symbol |
|---|---|---|
| $10^{12}$ | tera | T |
| $10^9$ | giga | G |
| $10^6$ | mega | M |
| $10^3$ | kilo | k |
| $10^2$ | hecto | h |
| $10^{-1}$ | deci | d |
| $10^{-2}$ | centi | c |
| $10^{-3}$ | milli | m |
| $10^{-6}$ | micro | μ |
| $10^{-9}$ | nano | n |
| $10^{-12}$ | pico | p |
| $10^{-15}$ | femto | f |

# Physical Constants

| | |
|---|---|
| Avogadro's number | $N_A = 6.022 \times 10^{23}\ \text{mol}^{-1}$ |
| Boltzmann's constant | $k = 1.381 \times 10^{-23}$ J/K |
| Electron charge magnitude | $e = 1.602 \times 10^{-19}$ C |
| Gas constant | $R = 8.315$ J/mol·K |
| Gravitational constant | $G = 6.673 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$ |
| Permeability of free space | $\mu_0 = 4\pi \times 10^{-7}$ T·m/A |
| Permittivity of free space | $\epsilon_0 = 8.854 \times 10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2$ |
| Planck's constant | $h = 6.626 \times 10^{-34}$ J·s |
| Mass of electron | $m_e = 9.109 \times 10^{-31}$ kg |
| Mass of neutron | $m_n = 1.675 \times 10^{-27}$ kg |
| Mass of proton | $m_p = 1.673 \times 10^{-27}$ kg |
| Speed of light in vacuum | $c = 2.998 \times 10^8$ m/s |

# Useful Data

### Air

| | |
|---|---|
| Density (20°C, 1 atm) | 1.20 kg/m$^3$ |
| Molecular mass | 29.0 g/mol |
| Speed of sound (20°C) | 1480 m/s |

### Water

| | |
|---|---|
| Density (4°C) | 1000 kg/m$^3$ |
| Latent heat of fusion | $3.35 \times 10^5$ J/kg |
| Latent heat of vaporization | $2.26 \times 10^6$ J/kg |
| Specific heat | 4190 J/kg·C° |
| Speed of sound (20°C) | 343 m/s |

### Earth

| | |
|---|---|
| Mass | $5.98 \times 10^{24}$ kg |
| Radius (mean) | $6.37 \times 10^6$ m |
| Distance from sun (mean) | $1.50 \times 10^{11}$ m |

### Moon

| | |
|---|---|
| Mass | $7.35 \times 10^{22}$ kg |
| Radius (mean) | $1.74 \times 10^6$ m |
| Distance from earth (mean) | $3.84 \times 10^8$ m |

### Sun

| | |
|---|---|
| Mass | $1.99 \times 10^{30}$ kg |
| Radius (mean) | $6.96 \times 10^8$ m |

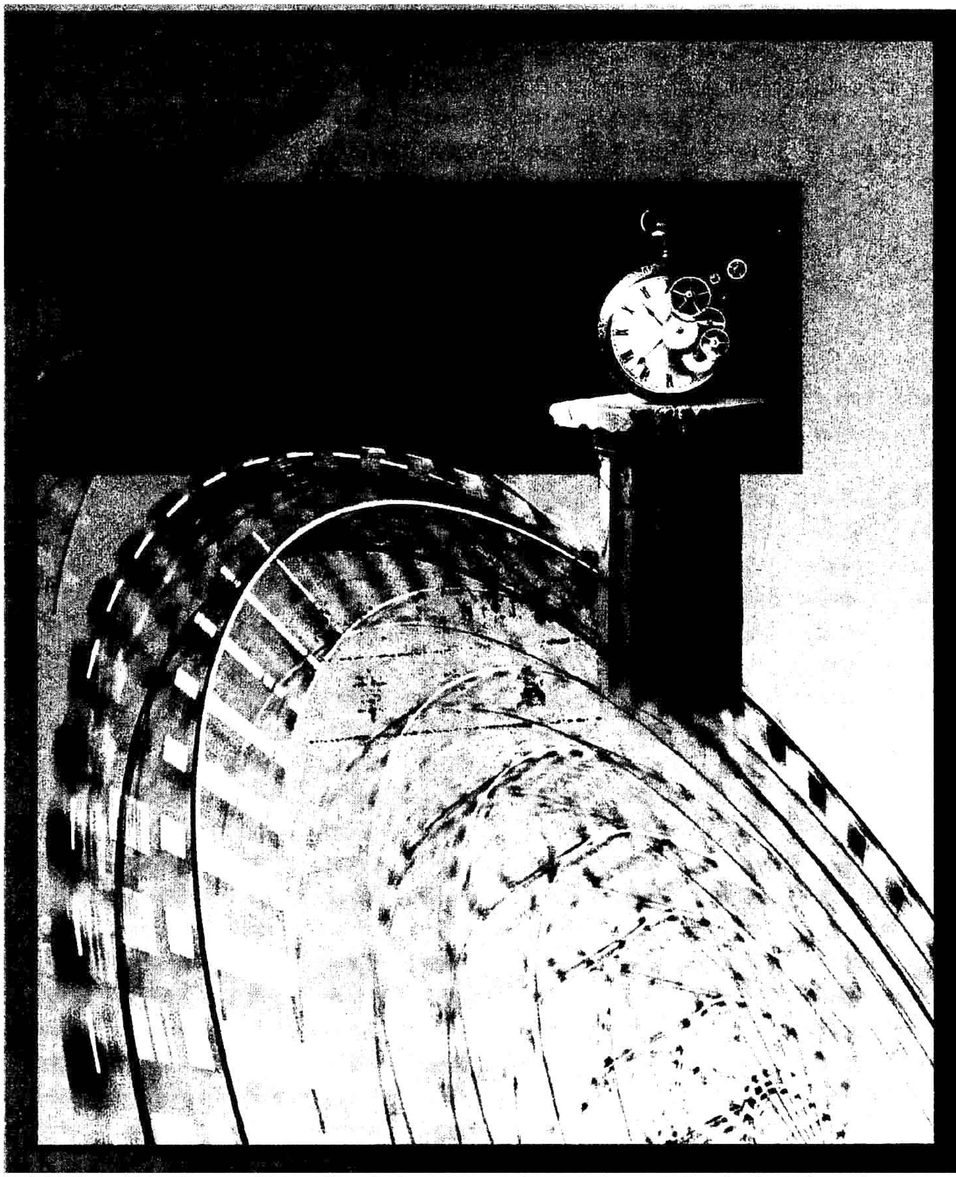
# Color Code

### Vectors

| | | | |
|---|---|---|---|
| Abstract | → | Electric current | → |
| Displacement | → | Electric field line | → |
| Velocity | → | Magnetic field line | → |
| Acceleration | → | Light ray | → |
| Force | → | Real object or image | ↑ |
| Electric Field | → | Virtual object or image | ↑ |
| Magnetic Field | → | | |

# COLLEGE

# PHYSICS



# Preface

## Why Study Physics?

Imagine you have lived your entire life without being able to see the world in color. Imagine you see only black and white. Then imagine that someone gives you a way to see color for the first time. Before you experience color vision, however, you could not know what you were missing. You would have only the word of others to imagine how wonderful it could be. Seeing the world without any understanding of physics is like seeing the world without color. It is being blind to much of the beauty, richness, and depth of the physical universe. A good course in physics provides the means to open this universe to you, to see the world with the insight that physics provides. More specifically, knowledge of physics allows you:

To begin to appreciate the diverse phenomena of the world in a new, more unified way, to see a world governed by physical principles, and to understand how these principles serve as a foundation for understanding other sciences such as biology and chemistry.

To be able to apply the principles of physics to the solution of problems and to understand how physical principles have been used to solve enormous technical problems, opening up new vistas of experience of the physical universe undreamed of 50 or 100 years ago—space exploration, lasers, electron microscopes, computer memory chips, magnetic resonance imaging, and so on.

To wonder about the mysteries of the physical universe that remain and the vistas that will unfold within your lifetime.

You are very likely taking physics because it is required for your major, and you may rightly regard it as a challenge, a means for realizing your professional goals. But if you can be open to some of the broader educational objectives, you may find your physics course to be a lasting, enriching experience, and you may even find that such an attitude enhances your chance for success.

## Goals of the Text

Designed for a 1-year course in college physics, using algebra and trigonometry, this text is the product of more than 20 years of experience teaching college physics. For more than 10 years I have worked to develop the best possible college physics textbook. The following are some general goals that have guided my work:

**1** Use the most direct, concise language possible to convey ideas.
**2** Use illustrations and photographs as effectively as possible to aid understanding.
**3** Improve the explanation of difficult concepts.
**4** Introduce abstract physical concepts wherever possible by appealing to common experiences that illustrate the concepts.
**5** Present applications of physical principles—to biology, modern technology, sports and other everyday activities—in a way that clearly distinguishes applications from physical principles.
**6** Present derivations in a way most likely to help, not hinder, understanding. Adapt both the style of derivations and placement of derivations to individual topics in such a way that the relationship of physical concepts is demonstrated in the clearest possible way.

7 Formulate new and interesting examples and problems, many drawn from real-life experiences, to make the college physics course more interesting for both students and professors.

# Features

## Organization

The overall organization of this text is very traditional. The following departures from tradition are intended to improve unity and coherence: a separate chapter on universal gravitation placed just after chapters 4 and 5 on Newton's laws and applications; a single chapter treating all mechanical waves, including sound, in an integrated way; an introduction to wave optics that begins with a qualitative overview of the wave properties of light, showing how diffraction and interference are related before each is discussed separately and quantitatively.

To allow the reader to quickly locate specific topics, I have made frequent use of subsection headings within sections of a chapter.

## Explanations

The text offers particularly good explanations of many difficult concepts, including instantaneous speed, relative motion, universal gravitation, energy, Archimedes' principle, surface tension and capillarity, entropy, the eye and visual acuity, measurement of time in relativity, and wave-particle duality. A completely original feature is an elementary, quantitative discussion of optical coherence. The treatment of electricity and magnetism is unusually thorough and effective.

## Applications

Numerous applications of physics to biology, technology, sports, and everyday life help motivate student interest. Every effort is made to distinguish applications from fundamental physical principles. For example, many applications are presented in examples and problems.

Each half of the book contains one extended biophysical application: in Chapter 11 the physics of fluids is applied to the human circulatory system, and in Chapter 25 optics is applied to the human eye. These unusually detailed biophysical applications are chosen for the richness of the results that follow from simple physical principles.

## Illustrations and Photographs

Great care and meticulous attention to detail has been given to the development of full-color art that would realize the enormous potential of pictures to teach physics. The text contains approximately 1100 drawings and over 400 photographs, nearly all of which were planned as the manuscript was written, so that words and pictures work together to convey ideas.

Illustrations accompanying end-of-chapter problems are particularly plentiful in mechanics, where they serve to ease the student toward increasingly abstract thinking. Three-dimensional perspective drawings are used extensively, especially in the chapter on magnetism. In the chapters on optics, unusually careful ray diagrams are provided, for example, to show chromatic aberration and image formation by a microscope.

Illustrations often accompany examples. These illustrations are placed within the body of an example for easy reference. Often an example contains two illustrations, one relating to the formulation of the question, and a second relating to the solution (a free body diagram, for example).

## Examples

Over 300 worked examples guide the student first to the solution of elementary problems and then to the solution of conceptually and/or mathematically more complex problems. A general problem-solving strategy is outlined in a special section preceding the problem set in Chapter 1. This strategy is then reinforced in the solution of examples throughout the book.

Particular attention is given to solution of "word problems" in kinematics. In Chapter 2 I introduce the technique of translating questions formulated in words to questions expressed in symbols. For example, the question "If a speed of 70 m/s is needed for a plane to leave the ground, how long a runway is required?" becomes "Find $x$ when $v = 70$ m/s." This kind of translation from words to symbols is surprisingly effective in helping students overcome their difficulty with words problems.

## Questions and Problems

The focus of student effort in a physics course is on problem solving. Therefore I have tried to make the over 2000 end-of-chapter questions and problems a strong feature of this text. They serve to build understanding of physical principles and to stimulate student interest in applications of physics to a wide variety of subjects, including biology and sports. Many reviewers have praised the originality and effectiveness of the problems.

The questions encourage students to build their qualitative, conceptual understanding of physics. Answers to odd-numbered questions are at the end of the questions in each chapter.

Problems are rated in difficulty by the number of stars appearing next to them: those with no stars are easiest, one-star problems are more difficult, and two-star problems are most difficult. Answers to odd-numbered problems are provided at the end of the book.

## Historical Insights

Historical background is provided in introducing certain topics, for example, universal gravitation, electromagnetic waves, and atomic theory. These are areas in which history provides insight into the meaning of physical concepts by showing how these concepts evolved. A secondary goal is to provide insight into the process of discovery in physics, revealing it as a human activity. *In Perspective* essays give additional historical material.

## Essays

Two kinds of essays are provided: 9 *In Perspective* historical essays and 12 *Closer Look* essays that involve physical concepts or applications. Both kinds of essays are intended to stimulate students to think about ideas beyond what is required for the course.

The *In Perspective* essays are mainly short biographies of physicists who have made some of the most important discoveries in physics: Galileo, Newton, Faraday, Einstein, Feynman, Hawking, and Curie. These are more than just a few paragraphs; they offer enough depth to humanize their subjects and sometimes to help understand what motivated their discoveries.

The *Closer Look* essays are discussions of physical principles and applications that encourage the student to think about subjects likely to arouse interest. For example, "Magic in the Sky" describes rare atmospheric optical effects such as the glory and Fata morgana. The "Energy to Run" explains, in terms of energy principles, why it is so much easier to ride a bicycle than it is to run at the same speed. "Electrical Effects in the Human Body" provides the biophysical basis for understanding why an electric shock that produces only a small electric current inside the body can nevertheless be lethal. "Biomagnetism" describes how magnetotectic bacteria have evolved in such a way as to take advantage of the earth's magnetic field. "Structure of the Retina and Color Sensitivity" describes the biophysics of the human eye. "General Relativity" shows how simple questions about relative motion led to a profound theory with amazing astronomical implications.

## Ancillaries

The following ancillaries are available with this text:

### Instructor's Manual with Complete Solutions

This manual presents answers and worked-out solutions to all problems in the text in a form that correlates closely with the text's approach to problem solving. Also included are sample course outlines, chapter outlines, overview of main concepts, learning objectives, media and supplementary resources, and answers to end-of-chapter conceptual questions.

### Instructor's Manual on Disk

The Instructor's Manual is also available on IBM and Macintosh floppy disk.

### Student Study Guide with Selected Solutions

The Study Guide contains chapter overviews, essential terms and concepts, sample problems and solutions, student drill problems with solutions, and solutions to selected odd-numbered problems (about 10%) from the text.

### Testbank

The printed testbank contains approximately 1200 problems and 300 concept-based questions. These problems and questions have been carefully prepared to complement the problem-solving style presented in the text.

### DIPLOMA Computerized Testbank

Available for IBM and Macintosh computers, this software offers the printed testbank in a form that enables instructors to select, edit, add, or delete questions and then construct and print tests and answers keys. A Gradebook segment features computerized record-keeping; a Proctor segment allows instructors to set up their own computer-aided tutorials. Graphics capabilities are also included.

### Transparency Acetates

More than 200 full-color transparency acetates feature some of the high-quality art in the text. The figures have been selected specifically for their instructional value. Images and labels are clear and large so that the acetates may be appreciated by students in the rear of large lecture halls.

### Slides

For added flexibility, the Transparency Acetates are also available as a set of 35-mm slides.

### Videodisc

The physics videodisc provides outstanding visual reinforcement of concepts and allows students to make first-hand observations about physics principles. The videodisc features a collection of demonstrations and animations that correlate directly with the text. All of the images in the transparency acetate collection have been placed on both sides of the videodisc for easy access.

### Videotape

The videotape offers the same demonstrations and animations found on the videodisc.

### Physics Quick Reference

This unique, pocket-sized supplement includes key concepts, equations, and illustrations from the text. It is shrink-wrapped free with each text.

### *Interactive Physics II*™ Problems Set Disk

This problems set disk contains selected examples and problems from the text set up in the *Interactive Physics* environment. The disk is to be used with Knowledge Revolution's *Interactive Physics II,* a powerful, dynamic simulator of the physical behavior of objects. IBM and Macintosh versions are available.

### *f(g) Scholar*™

This unique software tool by Future Graph, Inc. allows science students to solve and analyze numerical problems of all types. Featuring an algebraic calculator with more than 300 built-in functions, a spreadsheet optimized for science, a graphing/charting module, and a full drawing package, *f(g) Scholar* is also excellent for preparing lab reports or homework assignments. The Mosby Custom Version takes advantage of *f(g) Scholar's* database capabilities by offering 100 problems from the text set up and ready to be worked through plus the complete text of the *Physics Quick Reference* plus sample MCAT exam questions.

### *f(g) Scholar*™ ViewCalc Version

A full working version of this dynamic software tool—except that printing and file saving functions are disabled—is packaged *free* with each copy of *College Physics*. Included are 15 problems from the text set up and ready to run.

### Physics Multimedia CD-ROM

Mosby offers the ultimate electronic learning tool for college physics. Included on the CD-ROM are the following features: *f(g) Scholar* with 100 problems already worked out, the full contents of the *Interactive Physics II* Problems Set Disk, the complete set of videodisc motion video demonstrations and animations, the complete *Student Study Guide with Selected Solutions,* the complete *Physics Quick Reference,* and a selection of MCAT-style exam questions.

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# Brief Contents