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PHYSICS

Principles with Applications for *AP*

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Douglas C. Giancoli

ALWAYS LEARNING

PEARSON

PHYSICS

PRINCIPLES WITH APPLICATIONS for AP

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Fundamental Constants

Quantity	Symbol	Approximate Value	Current Best Value†
Speed of light in vacuum	c	3.00×10^8 m/s	2.99792458×10^8 m/s
Gravitational constant	G	$6.67 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2}$	$6.6742(10) \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2}$
Avogadro's number	N_A	$6.02 \times 10^{23}\ \mathrm{mol^{-1}}$	$6.0221415(10) \times 10^{23}\ \mathrm{mol^{-1}}$
Gas constant	R	$8.314\ \mathrm{J/mol \cdot K} = 1.99\ \mathrm{cal/mol \cdot K} = 0.0821\ \mathrm{L \cdot atm/mol \cdot K}$	$8.314472(15)\ \mathrm{J/mol \cdot K}$
Boltzmann's constant	k	1.38×10^{-23} J/K	$1.3806505(24) \times 10^{-23}$ J/K
Charge on electron	e	1.60×10^{-19} C	$1.60217653(14) \times 10^{-19}$ C
Stefan-Boltzmann constant	σ	$5.67 \times 10^{-8}\ \mathrm{W/m^2 \cdot K^4}$	$5.670400(40) \times 10^{-8}\ \mathrm{W/m^2 \cdot K^4}$
Permittivity of free space	$\epsilon_0 = (1/c^2\mu_0)$	$8.85 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2}$	$8.854187817\ldots \times 10^{-12}\ \mathrm{C^2/N \cdot m^2}$
Permeability of free space	μ_0	$4\pi \times 10^{-7}\ \mathrm{T \cdot m/A}$	$1.2566370614\ldots \times 10^{-6}\ \mathrm{T \cdot m/A}$
Planck's constant	h	$6.63 \times 10^{-34}\ \mathrm{J \cdot s}$	$6.6260693(11) \times 10^{-34}\ \mathrm{J \cdot s}$
Electron rest mass	m_e	$9.11 \times 10^{-31}\ \mathrm{kg} = 0.000549\ \mathrm{u} = 0.511\ \mathrm{MeV}/c^2$	$9.1093826(16) \times 10^{-31}\ \mathrm{kg} = 5.4857990945(24) \times 10^{-4}\ \mathrm{u}$
Proton rest mass	m_p	$1.6726 \times 10^{-27}\ \mathrm{kg} = 1.00728\ \mathrm{u} = 938.3\ \mathrm{MeV}/c^2$	$1.67262171(29) \times 10^{-27}\ \mathrm{kg} = 1.00727646688(13)\ \mathrm{u}$
Neutron rest mass	m_n	$1.6749 \times 10^{-27}\ \mathrm{kg} = 1.008665\ \mathrm{u} = 939.6\ \mathrm{MeV}/c^2$	$1.67492728(29) \times 10^{-27}\ \mathrm{kg} = 1.00866491560(55)\ \mathrm{u}$
Atomic mass unit (1 u)		$1.6605 \times 10^{-27}\ \mathrm{kg} = 931.5\ \mathrm{MeV}/c^2$	$1.66053886(28) \times 10^{-27}\ \mathrm{kg} = 931.494043(80)\ \mathrm{MeV}/c^2$

† CODATA (12/03), Peter J. Mohr and Barry N. Taylor, National Institute of Standards and Technology. Numbers in parentheses indicate one-standard-deviation experimental uncertainties in final digits. Values without parentheses are exact (i.e., defined quantities).

Other Useful Data

Joule equivalent (1 cal)	4.186 J
Absolute zero (0 K)	−273.15°C
Acceleration due to gravity at Earth's surface (avg.)	$9.80\ \mathrm{m/s^2}$ (= g)
Speed of sound in air (20°C)	343 m/s
Density of air (dry)	$1.29\ \mathrm{kg/m^3}$
Earth: Mass	5.98×10^{24} kg
Radius (mean)	6.38×10^3 km
Moon: Mass	7.35×10^{22} kg
Radius (mean)	1.74×10^3 km
Sun: Mass	1.99×10^{30} kg
Radius (mean)	6.96×10^5 km
Earth–Sun distance (mean)	149.6×10^6 km
Earth–Moon distance (mean)	384×10^3 km

The Greek Alphabet

Alpha	Α	α	Nu	Ν	ν
Beta	Β	β	Xi	Ξ	ξ
Gamma	Γ	γ	Omicron	Ο	o
Delta	Δ	δ	Pi	Π	π
Epsilon	Ε	ε	Rho	Ρ	ρ
Zeta	Ζ	ζ	Sigma	Σ	σ
Eta	Η	η	Tau	Τ	τ
Theta	Θ	θ	Upsilon	Υ	υ
Iota	Ι	ι	Phi	Φ	ϕ, φ
Kappa	Κ	κ	Chi	Χ	χ
Lambda	Λ	λ	Psi	Ψ	ψ
Mu	Μ	μ	Omega	Ω	ω

Values of Some Numbers

$\pi = 3.1415927$	$\sqrt{2} = 1.4142136$	$\ln 2 = 0.6931472$	$\log_{10} e = 0.4342945$
$e = 2.7182818$	$\sqrt{3} = 1.7320508$	$\ln 10 = 2.3025851$	1 rad = 57.2957795°

Mathematical Signs and Symbols

$\propto$	is proportional to	$\leq$	is less than or equal to
$=$	is equal to	$\geq$	is greater than or equal to
$\approx$	is approximately equal to	Σ	sum of
$\neq$	is not equal to	$\bar{x}$	average value of x
$>$	is greater than	Δx	change in x
$\gg$	is much greater than	$\Delta x \to 0$	Δx approaches zero
$<$	is less than	$n!$	$n(n-1)(n-2)\ldots(1)$
$\ll$	is much less than		

Properties of Water

Density (4°C)	$1.000\ \mathrm{kg/m^3}$
Heat of fusion (0°C)	333 kJ/kg (80 kcal/kg)
Heat of vaporization (100°C)	2260 kJ/kg (539 kcal/kg)
Specific heat (15°C)	$4186\ \mathrm{J/kg \cdot C^\circ}$ ($1.00\ \mathrm{kcal/kg \cdot C^\circ}$)
Index of refraction	1.33

Unit Conversions (Equivalents)

Length

1 in. = 2.54 cm
1 cm = 0.3937 in.
1 ft = 30.48 cm
1 m = 39.37 in. = 3.281 ft
1 mi = 5280 ft = 1.609 km
1 km = 0.6214 mi
1 nautical mile (U.S.) = 1.151 mi = 6076 ft = 1.852 km
1 fermi = 1 femtometer (fm) = 10^{-15} m
1 angstrom (Å) = 10^{-10} m = 0.1 nm
1 light-year (ly) = 9.461×10^{15} m
1 parsec = 3.26 ly = 3.09×10^{16} m

Volume

1 liter (L) = 1000 mL = 1000 cm^3 = $1.0 \times 10^{-3}\ m^3$ = 1.057 qt (U.S.) = 61.02 $in.^3$
1 gal (U.S.) = 4 qt (U.S.) = 231 $in.^3$ = 3.785 L = 0.8327 gal (British)
1 quart (U.S.) = 2 pints (U.S.) = 946 mL
1 pint (British) = 1.20 pints (U.S.) = 568 mL
1 m^3 = 35.31 ft^3

Speed

1 mi/h = 1.467 ft/s = 1.609 km/h = 0.447 m/s
1 km/h = 0.278 m/s = 0.621 mi/h
1 ft/s = 0.305 m/s = 0.682 mi/h
1 m/s = 3.281 ft/s = 3.600 km/h = 2.237 mi/h
1 knot = 1.151 mi/h = 0.5144 m/s

Angle

1 radian (rad) = 57.30° = 57°18′
1° = 0.01745 rad
1 rev/min (rpm) = 0.1047 rad/s

Time

1 day = 8.64×10^4 s
1 year = 3.156×10^7 s

Mass

1 atomic mass unit (u) = 1.6605×10^{-27} kg
1 kg = 0.0685 slug
[1 kg has a weight of 2.20 lb where $g = 9.80\ m/s^2$.]

Force

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

Energy and Work

1 J = 10^7 ergs = 0.738 ft·lb
1 ft·lb = 1.36 J = 1.29×10^{-3} Btu = 3.24×10^{-4} kcal
1 kcal = 4.186×10^3 J = 3.97 Btu
1 eV = 1.602×10^{-19} J
1 kWh = 3.60×10^6 J = 860 kcal

Power

1 W = 1 J/s = 0.738 ft·lb/s = 3.42 Btu/h
1 hp = 550 ft·lb/s = 746 W

Pressure

1 atm = 1.013 bar = $1.013 \times 10^5\ N/m^2$
= 14.7 lb/$in.^2$ = 760 torr
1 lb/$in.^2$ = $6.90 \times 10^3\ N/m^2$
1 Pa = 1 N/m^2 = 1.45×10^{-4} lb/$in.^2$

SI Derived Units and Their Abbreviations

Quantity	Unit	Abbreviation	In Terms of Base Units†
Force	newton	N	$kg \cdot m/s^2$
Energy and work	joule	J	$kg \cdot m^2/s^2$
Power	watt	W	$kg \cdot m^2/s^3$
Pressure	pascal	Pa	$kg/(m \cdot s^2)$
Frequency	hertz	Hz	s^{-1}
Electric charge	coulomb	C	$A \cdot s$
Electric potential	volt	V	$kg \cdot m^2/(A \cdot s^3)$
Electric resistance	ohm	Ω	$kg \cdot m^2/(A^2 \cdot s^3)$
Capacitance	farad	F	$A^2 \cdot s^4/(kg \cdot m^2)$
Magnetic field	tesla	T	$kg/(A \cdot s^2)$
Magnetic flux	weber	Wb	$kg \cdot m^2/(A \cdot s^2)$
Inductance	henry	H	$kg \cdot m^2/(s^2 \cdot A^2)$

† kg = kilogram (mass), m = meter (length), s = second (time), A = ampere (electric current).

Metric (SI) Multipliers

Prefix	Abbreviation	Value
yotta	Y	10^{24}
zeta	Z	10^{21}
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^9
mega	M	10^6
kilo	k	10^3
hecto	h	10^2
deka	da	10^1
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}
zepto	z	10^{-21}
yocto	y	10^{-24}

PHYSICS

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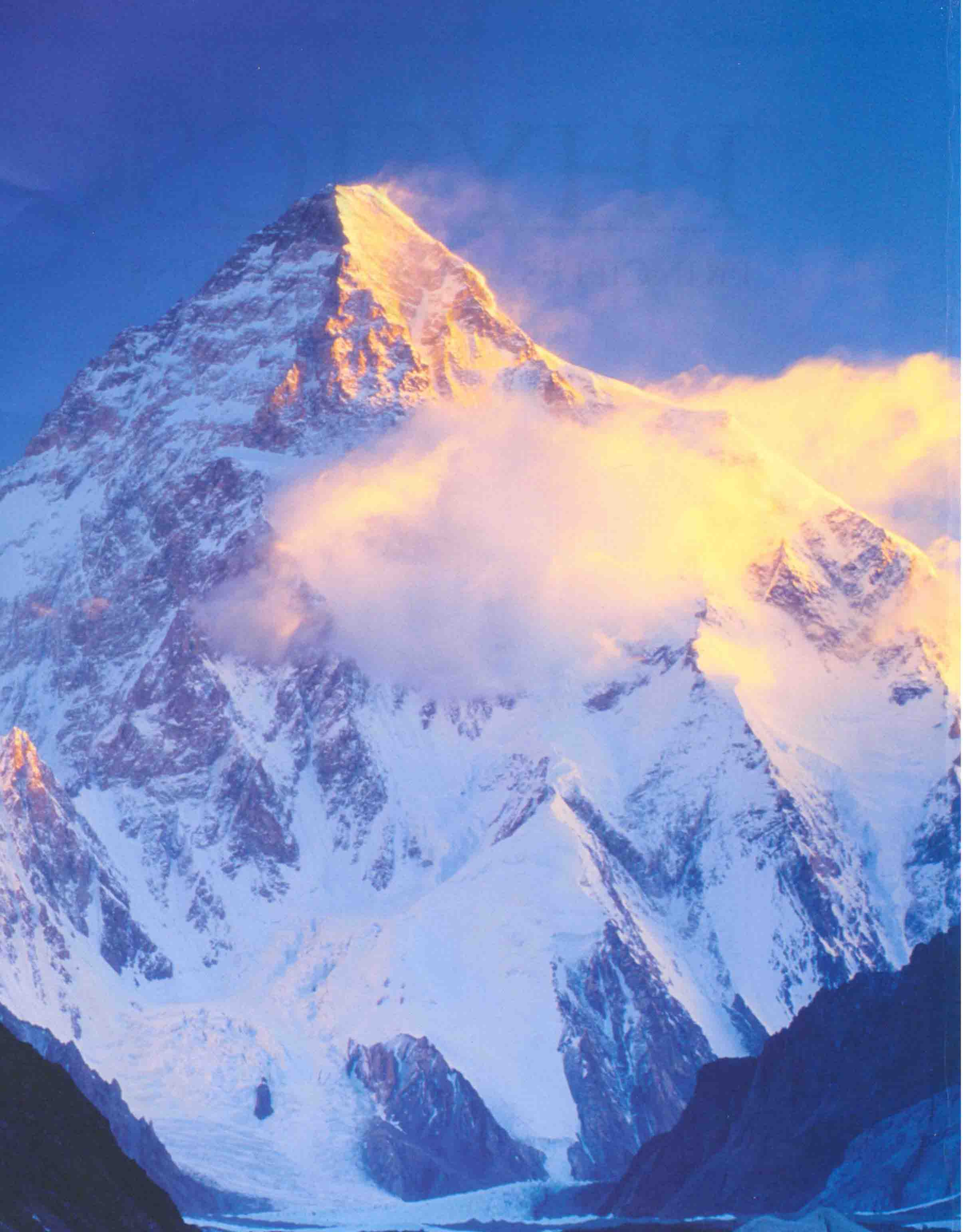

Preface

See the World through Eyes that Know Physics

This book is written for students. It has been written to give students a thorough understanding of the basic concepts of physics in all its aspects, from mechanics to modern physics. It aims to explain physics in a readable and interesting manner that is accessible and clear, and to teach students by anticipating their needs and difficulties without oversimplifying. A second objective is to show students how useful physics is in their own lives and future professions by means of interesting applications. In addition, much effort has gone into techniques and approaches for solving problems.

This textbook is especially suited for students taking a one-year introductory course in physics that uses algebra and trigonometry but not calculus. Many of these students are majoring in biology or (pre)medicine, and others may be in architecture, technology, or the earth or environmental sciences. Many applications to these fields are intended to answer that common student query: "Why must I study physics?" The answer is that physics is fundamental to a full understanding of these fields, and here they can see how. Physics is all about us in the everyday world. It is the goal of this book to help students "see the world through eyes that know physics."

NEW ▶ Some of the new features in this sixth edition include (1) in-text Exercises for students to check their understanding; (2) new Approach paragraphs for worked-out Examples; (3) new Examples that step-by-step follow each Problem Solving Box; (4) new physics such as a rigorously updated Chapter 33 on cosmology and astrophysics to reflect the latest results in the recent "Cosmological Revolution"; and (5) new applications such as detailed physics-based descriptions of liquid crystal screens (LCD), digital cameras (with CCD), and expanded coverage of electrical safety and devices. These and other new aspects are highlighted below.

Physics and How to Understand It

I have avoided the common, dry, dogmatic approach of treating topics formally and abstractly first, and only later relating the material to the students' own experience. My approach is to recognize that physics is a description of reality and thus to start each topic with concrete observations and experiences that students can directly relate to. Then we move on to the generalizations and more formal treatment of the topic. Not only does this make the material more interesting and easier to understand, but it is closer to the way physics is actually practiced.

A major effort has been made to not throw too much at students reading the first few chapters. The basics have to be learned first; many aspects can come later, when the students are more prepared. If we don't overwhelm students with too much detail, especially at the start, maybe they can find physics interesting, fun, and helpful—and those who were afraid may lose their fear.

The *great laws of physics* are emphasized by giving them a tan-colored screen and a marginal note in capital letters enclosed in a rectangle. All important equations are given a number to distinguish them from less useful ones. To help make clear which equations are general and which are not, the limitations of important equations are given in brackets next to the equation, such as

$$x = x_0 + v_0 t + \tfrac{1}{2} a t^2. \qquad \text{[constant acceleration]}$$

Mathematics can be an obstacle to student understanding. I have aimed at including all steps in a derivation. Important mathematical tools, such as addition of vectors and trigonometry, are incorporated in the text where first needed, so they come with a context rather than in a scary introductory Chapter. Appendices contain a review of algebra and geometry (plus a few advanced topics: rotating reference frames, inertial forces, Coriolis effect; heat capacities of gases and equipartition of energy; Lorentz transformations). Système International (SI) units are used throughout. Other metric and British units are defined for informational purposes.

Chapter 1 is not a throwaway. It is fundamental to physics to realize that every measurement has an *uncertainty*, and how significant figures are used to reflect that. Converting units and being able to make rapid *estimates* are also basic. The cultural aspects at the start of Chapter 1 broaden a person's understanding of the world but do not have to be covered in class.

The many *applications* sometimes serve only as examples of physical principles. Others are treated in depth. They have been carefully chosen and integrated into the text so as not to interfere with the development of the physics, but rather to illuminate it. To make it easy to spot the applications, a Physics Applied marginal note is placed in the margin.

Color is used pedagogically to bring out the physics. Different types of vectors are given different colors (see the chart on page xxv). This book has been printed in 5 colors (5 passes through the presses) to provide better variety and definition for illustrating vectors and other concepts such as fields and rays. The photographs opening each Chapter, some of which have vectors superimposed on them, have been chosen so that the accompanying caption can be a sort of summary of the Chapter.

Some of the **new** aspects of physics and pedagogy in this sixth edition are:

Cosmological Revolution: The latest results in cosmology and astrophysics are presented with the generous help of top experts in the field. We give readers the latest results and interpretations from the present, ongoing "Golden Age of Cosmology."

Greater clarity: No topic, no paragraph in this book was overlooked in the search to improve the clarity of the presentation. Many changes and clarifications have been made, both small and not so small. One goal has been to eliminate phrases and sentences that may slow down the principle argument: keep to the essentials at first, give the elaborations later.

Vector notation, arrows: The symbols for vector quantities in the text and Figures now have a tiny arrow over them, so they are similar to what a professor writes by hand in lecture. The letters are still the traditional boldface: thus $\vec{\mathbf{v}}$ for velocity, $\vec{\mathbf{F}}$ for force. ◀ NEW

Exercises within the text, for students to check their understanding. Answers are given at the end of the Chapter. ◀ NEW

Step-by Step Examples, after a Problem Solving Box, as discussed on page xvii. ◀ NEW

Conceptual Examples are not a new feature, but there are some new ones.

Examples modified: more math steps are spelled out, and many new Examples added: see page xvii.

Page layout: Complete Derivations. Even more than in the previous edition, serious attention has been paid to how each page is formatted. Great effort has been made to keep important derivations and arguments on facing pages. Students then don't have to turn back and forth. Throughout the book readers see before them, on two facing pages, an important slice of physics.

Subheads: Many of the Sections within a Chapter are now divided into subsections, thus breaking up the topics into more manageable "bites." They allow "pauses" for the students to rest or catch their breath. ◀ NEW

Marginal notes: Caution. Margin notes, in blue, point out main topics acting as a sort of outline and as an aid to find topics in review. They also point out applications and problem-solving hints. A new type, labeled CAUTION, points out possible misunderstandings discussed in the adjacent text. NEW ▶

Deletions. To keep the book from being too long, and also to reduce the burden on students in more advanced topics, many topics have been shortened or streamlined, and a few dropped.

New Physics Topics and Major Revisions

Here is a list of major changes or additions, but there are many others:

- Symmetry used more, including for solving Problems
- NEW ▶ Dimensional analysis, optional (Ch. 1)
- More graphs in kinematics (Ch. 2)
- Engine efficiency (Chs. 6, 15)
- Work-energy principle, and conservation of energy: new subsection (Ch. 6); carried through in thermodynamics (Ch. 15) and electricity (Ch. 17)
- NEW ▶ Force on tennis ball by racket (Ch. 7)
- NEW ▶ Airplane wings, curve balls, sailboats, and other applications of Bernoulli's principle: improved and clarified with new material (Ch. 10)
- Distinguish wave interference in space and in time (beats) (Ch. 11)
- Doppler shift for light (Ch. 12 now, as well as Ch. 33)
- NEW ▶ Giant star radius (Ch. 14)
- First law of thermodynamics rewritten and extended, connected better to work-energy principle and energy conservation (Ch. 15)
- Energy resources shortened (Ch. 15)
- NEW ▶ SEER rating (Ch. 15)
- NEW ▶ Separation of charge in nonconductors (Ch. 16)
- NEW ▶ Gauss's law, optional (Ch. 16)
- NEW ▶ Photocopiers and computer printers (Ch. 16)
- Electric force and field directions emphasized more (Chs. 16, 17)
- Electric potential related better to work, more detail (Ch. 17)
- NEW ▶ Dielectric effect on capacitor with and without connection to voltage plus other details (Ch. 17)
- NEW ▶ Parallel-plate capacitor derivation, optional (Ch. 17)
- NEW ▶ Electric hazards, grounding, safety, current interrupters: expanded with much new material (Chs. 17, 18, 19 especially, 20, 21)
- NEW ▶ Electric current, misconceptions discussed in Chapter 18
- Superconductivity updated (Ch. 18)
- Terminal voltage and emf reorganized, with more detail (Ch. 19)
- Magnetic materials shortened (Ch. 20)
- NEW ▶ Right-hand rules summarized in a Table (Ch. 20)
- Faraday's and Lenz's laws expanded (Ch. 21)
- AC circuits shortened (Ch. 21), displacement current downplayed (Ch. 22)
- NEW ▶ Radiation pressure and momentum of EM waves (Ch. 22)
- NEW ▶ Where to see yourself in a mirror; where you can actually *see* a lens image (Ch. 23)
- NEW ▶ Liquid crystal displays (LCD) (Ch. 24)
- NEW ▶ Physics behind digital cameras and CCD (Ch. 25)
- NEW ▶ Seeing under water (Ch. 25)
- Relativistic mass redone (Ch. 26)
- NEW ▶ Revolutionary results in cosmology: flatness and age of universe, WMAP, SDSS, dark matter, and dark energy (Ch. 33)
- NEW ▶ Specific heats of gases, equipartition of energy (Appendix)

Problem Solving, with New and Improved Approaches

Being able to solve problems is a valuable technique in general. Solving problems is also an effective way to understand the physics more deeply. Here are some of the ways this book uses to help students become effective problem solvers.

Problem Solving Boxes, about 20 of them, are found throughout the book (there is a list on p. xiii.). Each one outlines a step-by-step approach to solving problems in general, or specifically for the material being covered. The best students may find these "boxes" unnecessary (they can skip them), but many students may find it helpful to be reminded of the general approach and of steps they can take to get started. The general Problem Solving Box in Section 4–9 is placed there, after students have had some experience wrestling with problems, so they may be motivated to read it with close attention. Section 4–9 can be covered earlier if desired. Problem Solving Boxes are not intended to be a prescription, but rather a guide. Hence they sometimes follow the Examples to serve as a summary for future use.

Problem Solving Sections (such as Sections 2–6, 3–6, 4–7, 6–7, 8–6, and 13–8) are intended to provide extra drill in areas where solving problems is especially important.

Examples: Worked-out Examples, each with a title for easy reference, fall into four categories:

(1) The majority are regular worked-out Examples that serve as "practice problems." New ones have been added, a few old ones have been dropped, and many have been reworked to provide greater clarity, more math steps, more of "why we do it this way," and with the new Approach paragraph more discussion of the reasoning and approach. The aim is to "think aloud" with the students, leading them to develop insight. The level of the worked-out Examples for most topics increases gradually, with the more complicated ones being on a par with the most difficult Problems at the end of each Chapter. Many Examples provide relevant applications to various fields and to everyday life.

(2) ***Step-by-step Examples:*** After many of the Problem Solving Boxes, the next Example is done step-by-step following the steps of the preceding Box, just to show students how the Box can be used. Such solutions are long and can be redundant, so only one of each type is done in this manner. ◀ NEW

(3) ***Estimating Examples,*** roughly 10% of the total, are intended to develop the skills for making order-of-magnitude estimates, even when the data are scarce, and even when you might never have guessed that any result was possible at all. See, for example, Section 1–7, Examples 1–6 to 1–9.

(4) ***Conceptual Examples:*** Each is a brief Socratic question intended to stimulate student response before reading the Response given.

APPROACH paragraph: Worked-out numerical Examples now all have a short introductory paragraph before the Solution, outlining an approach and the steps we can take to solve the given problem. ◀ NEW

NOTE: Many Examples now have a brief "note" after the Solution, sometimes remarking on the Solution itself, sometimes mentioning an application, sometimes giving an alternate approach to solving the problem. These new Note paragraphs let the student know the Solution is finished, and now we mention a related issue(s). ◀ NEW

Additional Examples: Some physics subjects require many different worked-out Examples to clarify the issues. But so many Examples in a row can be overwhelming to some students. In those places, a subhead "Additional Example(s)" is meant to suggest to students that they could skip these in a first reading. When students include them during a second reading of the Chapter, they can give power to solve a greater range of Problems. ◀ NEW

Exercises within the text, after an Example or a derivation, which give students a chance to see if they have understood enough to answer a simple question or do a simple calculation. Answers are given at the bottom of the last page of each Chapter. ◀ NEW

Problems at the end of each Chapter have been increased in quality and quantity. Some old ones have been replaced or rewritten to make them clearer, and/or have had their numerical values changed. Each Chapter contains a large group of Problems arranged by Section and graded according to (approximate) difficulty: level I Problems are simple, designed to give students confidence; level II are "normal" Problems, providing more of a challenge and often the combination of two different concepts; level III are the most complex and are intended as "extra credit" Problems that will challenge even superior students. The arrangement by Section number is to help the instructors choose which material they want to emphasize, and means that those Problems depend on material up to and including that Section: earlier material may also be relied upon.
General Problems are unranked and grouped together at the end of each Chapter, accounting for perhaps 30% of all Problems. These are not necessarily more difficult, but they may be more likely to call on material from earlier Chapters. They are useful for instructors who want to give students a few Problems without the clue as to what Section must be referred to or how hard they are.
Questions, also at the end of each Chapter, are conceptual. They help students to use and apply the principles and concepts, and thus deepen their understanding (or let them know they need to study more).

Assigning Problems

I suggest that instructors assign a significant number of the level I and level II Problems, as well as a small number of General Problems, and reserve level III Problems only as "extra credit" to stimulate the best students. Although most level I problems may seem easy, they help to build self-confidence—an important part of learning, especially in physics. Answers to odd-numbered Problems are given in the back of the book.

Organization

The general outline of this new edition retains a traditional order of topics: mechanics (Chapters 1 to 9); fluids, vibrations, waves, and sound (Chapters 10 to 12); kinetic theory and thermodynamics (Chapters 13 to 15); electricity and magnetism (Chapters 16 to 22); light (Chapters 23 to 25); and modern physics (Chapters 26 to 33). Nearly all topics customarily taught in introductory physics courses are included here.

The tradition of beginning with mechanics is sensible because it was developed first, historically, and because so much else in physics depends on it. Within mechanics, there are various ways to order topics, and this book allows for considerable flexibility. I prefer to cover statics after dynamics, partly because many students have trouble with the concept of force without motion. Furthermore, statics is a special case of dynamics—we study statics so that we can prevent structures from becoming dynamic (falling down). Nonetheless, statics (Chapter 9) could be covered earlier after a brief introduction to vectors. Another option is light, which I have placed after electricity and magnetism and EM waves. But light could be treated immediately after waves (Chapter 11). Special relativity (Chapter 26) could be treated along with mechanics, if desired—say, after Chapter 7.

Not every Chapter need be given equal weight. Whereas Chapter 4 or Chapter 21 might require $1\frac{1}{2}$ to 2 weeks of coverage, Chapter 12 or 22 may need only $\frac{1}{2}$ week or less. Because Chapter 11 covers standing waves, Chapter 12 could be left to the students to read on their own if little class time is available.

The book contains more material than can be covered in most one-year courses. Yet there is great flexibility in choice of topics. Sections marked with a star (*) are considered optional. They contain slightly more advanced physics material (perhaps material not usually covered in typical courses) and/or interesting applications. They contain no material needed in later Chapters, except perhaps in later optional Sections. Not all unstarred Sections must be covered; there remains considerable flexibility in the choice of material. For a brief course, all optional material could be dropped, as well as major parts of Chapters 10, 12, 19, 22, 28, 29, 32, and 33, and perhaps selected parts of Chapters 7, 8, 9, 15, 21, 24, 25, and 31. Topics not covered in class can be a resource to students for later study.

New Applications

Relevant applications of physics to biology and medicine, as well as to architecture, other fields, and everyday life, have always been a strong feature of this book, and continue to be. Applications are interesting in themselves, plus they answer the students' question, "Why must I study physics?" New applications have been added. Here are a few of the new ones (see list after Table of Contents, pages xii and xiii).

◀ ALL ARE NEW

- Digital cameras, charge coupled devices (CCD) (Ch. 25)
- Liquid Crystal Displays (LCD) (Ch. 24)
- Electric safety, hazards, and various types of current interrupters and circuit breakers (Chs. 17, 18, 19, 20, 21)
- Photocopy machines (Ch. 16)
- Inkjet and Laser printers (Ch. 16)
- World's tallest peaks (unit conversion, Ch. 1)
- Airport metal detectors (Ch. 21)
- Capacitor uses (Ch. 17)
- Underwater vision (Ch. 25)
- SEER rating (Ch. 15)
- Curve ball (Ch. 10)
- Jump starting a car (Ch. 19)
- *RC* circuits in pacemakers, turn signals, wipers (Ch. 19)
- Digital voltmeters (Ch. 19)

Thanks

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