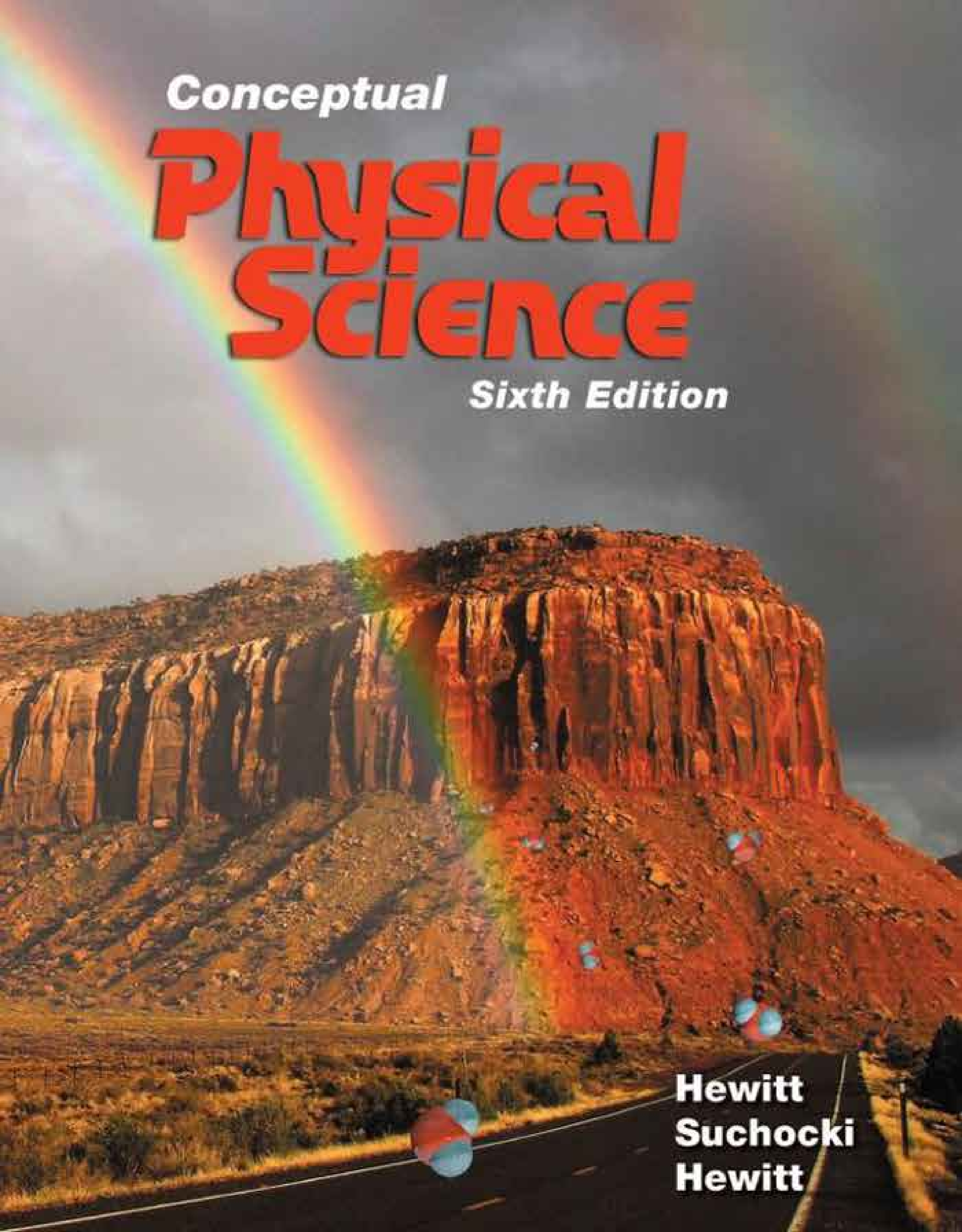


Conceptual

Physical Science

Sixth Edition

Hewitt
Suchocki
Hewitt

PHYSICAL CONSTANTS

Name	Symbol	Value
Speed of light	c	2.9979×10^8 m/s
Planck's constant	h	$6.6260755 \times 10^{-34}$ J · s
		4.1356692×10^{15} eV · s
Gravitational constant	G	6.67259×10^{-11} N · m²/kg²
Charge of electron	e	1.602×10^{-19} C
Mass of electron	m_e	$9.1093897 \times 10^{-31}$ kg
		0.51099906 MeV
Mass of proton	m_p	$1.6726231 \times 10^{-27}$ kg
		938.27231 MeV
Mass of neutron	m_n	$1.6749286 \times 10^{-27}$ kg
		939.56563 MeV
Avogadro's number	N_A	6.0221367×10^{23}/mol
		1 mole $= 6.022 \times 10^{23}$ particles
Unified atomic mass unit	u	$1.6605402 \times 10^{-27}$ kg
		931.49432 MeV

PHYSICAL PROPERTIES

Name	Value
Acceleration of gravity at Earth's surface, g	9.81 m/s²
Mass of Sun	1.99×10^{30} kg
Radius of Sun	6.96×10^8 m
Mass of Earth	5.98×10^{24} kg
Radius of Earth (equatorial)	6.37×10^6 m
Radius of Earth's orbit	1.50×10^{11} m = 1 AU
Mass of Moon	7.36×10^{22} kg
Radius of Moon	1.74×10^6 m
Radius of Moon's orbit	3.84×10^8 m

CONVERSION FACTORS

Length, Area, Volume

1 inch = 2.54 cm (exact)
1 ft = 30.48 cm (exact)
1 m = 39.37 in.
1 mi = 1.6093440 km
1 liter $= 10^3$ cm³ $= 10^{-3}$ m³

Time

1 year $= 365\frac{1}{4}$ day $= 3.1558 \times 10^7$ s
1 d = 86,400 s
1 h = 3600 s

Mass

1 kg = 1000 g
1 kg weighs about 2.205 lb

Pressure

1 Pa = 1 N/m²
1 atm $= 1.013 \times 10^5$ Pa
1 lb/in.² = 6895 Pa

Energy and Power

1 cal = 4.187 J
1 kWh $= 3.60 \times 10^6$ J
1 eV $= 1.602 \times 10^{-19}$ J
1 u = 931.5 MeV
1 hp = 746 W

Speed

1 m/s = 3.60 km/h = 2.24 mi/h
1 km/h = 0.621 mi/h

Force

1 lb = 4.448 N

NUMBERS EXPRESSED IN SCIENTIFIC NOTATION

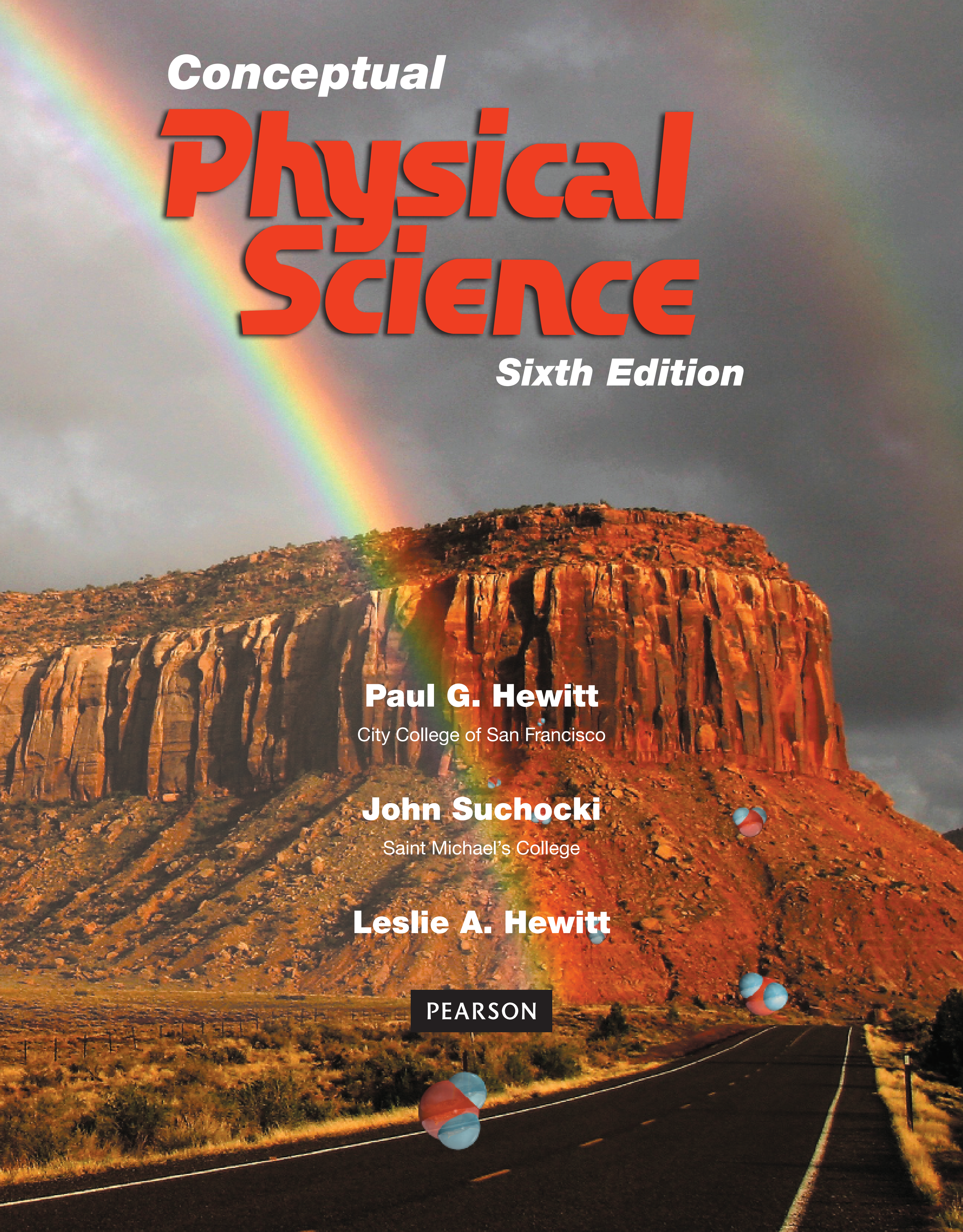
1 000 000	=	$10 \times 10 \times 10 \times 10 \times 10 \times 10$	$= 10^6$
100 000	=	$10 \times 10 \times 10 \times 10 \times 10$	$= 10^5$
10 000	=	$10 \times 10 \times 10 \times 10$	$= 10^4$
1000	=	$10 \times 10 \times 10$	$= 10^3$
100	=	10×10	$= 10^2$
10	=	10	$= 10^1$
1	=	1	$= 10^0$
0.1	=	1/10	$= 10^{-1}$
0.01	=	$1/100 = 1/10^2$	$= 10^{-2}$
0.001	=	$1/1000 = 1/10^3$	$= 10^{-3}$
0.000 1	=	$1/10\,000 = 1/10^4$	$= 10^{-4}$
0.0 000 1	=	$1/100\,000 = 1/10^5$	$= 10^{-5}$
0.00 000 1	=	$1/1\,000\,000 = 1/10^6$	$= 10^{-6}$

PHYSICAL DATA

Speed of light in a vacuum	$= 2.9979 \times 10^8$ m/s
Speed of sound (20°C, 1 atm)	= 343 m/s
Standard atmospheric pressure	$= 1.01 \times 10^5$ Pa
1 light-year	$= 9.461 \times 10^{12}$ km
1 astronomical unit (A.U.), (average Earth–Sun distance)	$= 1.50 \times 10^{11}$ m
Average Earth–Moon distance	$= 3.84 \times 10^8$ m
Equatorial radius of the Sun	$= 6.96 \times 10^8$ m
Equatorial radius of Jupiter	$= 7.14 \times 10^7$ m
Equatorial radius of the Earth	$= 6.37 \times 10^6$ m
Equatorial radius of the Moon	$= 1.74 \times 10^6$ m
Average radius of hydrogen atom	$= 5 \times 10^{-11}$ m
Mass of the Sun	$= 1.99 \times 10^{30}$ kg
Mass of Jupiter	$= 1.90 \times 10^{27}$ kg
Mass of the Earth	$= 5.98 \times 10^{24}$ kg
Mass of the Moon	$= 7.36 \times 10^{22}$ kg
Proton mass	$= 1.6726 \times 10^{-27}$ kg
Neutron mass	$= 1.6749 \times 10^{-27}$ kg
Electron mass	$= 9.1 \times 10^{-31}$ kg
Electron charge	$= 1.602 \times 10^{-19}$ C

STANDARD ABBREVIATIONS

A	ampere	g	gram	M	molarity
amu	atomic mass unit	h	hour	min	minute
atm	atmosphere	hp	horsepower	mph	mile per hour
Btu	British thermal unit	Hz	Hertz	N	newton
C	coulomb	in.	inch	Pa	pascal
°C	degree Celsius	J	joule	psi	pound per square inch
cal	calorie	K	kelvin	s	second
eV	electron volt	kg	kilogram	V	volt
°F	degree Fahrenheit	lb	pound	W	watt
ft	foot	m	meter	Ω	ohm



Conceptual Physical Science

Sixth Edition

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Saint Michael's College

Leslie A. Hewitt

PEARSON

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Library of Congress Cataloging-in-Publication Data

Hewitt, Paul G. | Suchocki, John. | Hewitt, Leslie A.
Conceptual physical science / Paul G. Hewitt, John Suchocki, Leslie A. Hewitt.
Sixth edition. | Boston: Pearson, 2015. | Includes bibliographical references and index.
LCCN 2015038973 | ISBN 9780134060491
LCSH: Physical sciences—Textbooks.
LCC Q158.5 .H48 2015 | DDC 500.2—dc23
LC record available at http://lccn.loc.gov/201503897
<http://lccn.loc.gov/2015038973>

1 2 3 4 5 6 7 8 9 10—V311—21 20 19 18 17 16

PEARSON

www.pearsonhighered.com

ISBN 10: 0-13-406049-0
ISBN 13: 978-0-13-406049-1

To inspirational teachers
Bruce Novak and Dean Baird

Brief Contents

Detailed Contents

The Conceptual Physical Science Photo Album

This is a very personal book with many photographs of family and friends. We dedicate this edition to physics teacher Dean Baird, our laboratory manual author, and to physics teacher Bruce Novak who assisted in making this the best edition ever. Dean, a Presidential Awardee for Excellence in Mathematics and Science Teaching, is also the photographer of this edition's cover. Many of Dean's photos appear throughout the book. Dean is shown on pages 273, 579, and 746. Physics teacher Bruce is also a talented photographer with several new photos in various chapters. (All photographs are listed in the Photo Credits pages at the end of the book). Bruce is shown on page 283, and with his wife Linda on page 742. Bruce's mom is shown on page 147. This 6th edition is a better book because of the inputs of Bruce and Dean.

Four part-opener photos of this book begin with little Charlotte Ackerman in Part 1 on page 13. Part 2 opens with John's nephews and niece Liam, Bo, and Neve Hopwood on page 293. Part 3 opens with Leslie's daughter Emily Abrams on page 533. Lastly, John's and Leslie's cousin, space-engineer Mike Lucas, opens Part 4 on page 725.

The authors' families begin with Paul's wife Lillian on pages 52, 169, 191, 249, 285, and 298. Lil's mom, Siu Bik Lee, makes use of solar power, and late dad, Wai Tsan Lee, shows magnetic induction on pages 183 and 225, with photos of niece Allison Lee Wong and nephew Erik Lee Wong on page 180. Paul's late wife, Millie Luna Hewitt, illustrates intriguing physics in her kitchen on page 171. Paul and Millie's eldest daughter, Jean Hurrell, is on page 149, and is also shown with her daughters Marie and Kara Mae on page 270 and Jean's husband Phil is on page 272. Marie appears again on page 23, and Kara Mae on page 46. Son Paul is on pages 154 and 703, and his former wife Ludmila shows crossed Polaroids on page 292. A photo of their daughter Grace opens the Prologue on page 1. Grace joins her brother Alexander and Leslie's daughters Megan and Emily Abrams for a series of group photos on page 285. Alexander airlifting on his skateboard is on page 105. Paul's first grandchild, Manuel Hewitt, swings as a youngster on page 267, and cooks as an executive chef on page 153.

Paul's sister (John's mom), Marjorie Hewitt Suchocki (pronounced Su-hock-ee), a retired theologian, shows reflectivity on page 276. Paul's brother Dave with his wife Barbara pump water on page 134. Paul's younger brother Steve shows Newton's third law with his daughter Gretchen on page 58. Gretchen's photo of the sky-blue Celeste River in her native Costa Rica is on page 286. Steve's eldest daughter Stephanie, a schoolteacher, demonstrates refraction on page 298.

Chemistry author John, who in his "other life" is John Andrew, singer and songwriter, plays his guitar on page 232. He is shown again walking barefoot on red-hot coals on the opening photo of Chapter 7. His wife Tracy, with son Ian, is shown in Figure 12.3 and with son Evan on page 364. Daughter Maitreya is eyeing ice cream on page 500 and brushing her teeth with her dear friend Annabelle Creech on page 383. John's nephew Graham Orr appears at ages 7 and 21 on page 407, demonstrating how water is essential for growth. The

Suchocki dog, Sam, pants on page 178. The "just-married" John and Tracy are flanked by John's sisters Cathy Candler and Joan Lucas on page 261. (Tracy's wedding ring is prominently shown on page 357.) Sister Joan is riding her horse on page 25. Cousin George Webster looks through his scanning electron microscope on page 320. Dear friends from John's years teaching in Hawaii include Rinchen Trashi on page 316 as well as Kai Dodge and Maile Ventura on page 493. Vermont friend Nikki Jiraff is seen carbonating water on page 427.

On page 326, Earth-Science author Leslie at age 16 illustrates the wonderful idea that we're all made of stardust. As an adult, Leslie sits on an ancient sand dune with her daughter Megan on page 629. Leslie's husband, Bob Abrams (a hydrogeologist), is shown on page 627. Megan, illustrates cooling by expansion on page 171, magnetic induction on page 221, and does a mineral scratch test on page 542. Younger daughter Emily uses a deck of cards to show how ice crystals slip on page 623, and on page 713 demonstrates counterclockwise rotation. On page 619, Bob, Megan, and Emily stand beside steep canyon walls carved by years of stream erosion. Leslie's cousin, Mike Luna, in his spiffy Corvette is on page 118. Leslie's second cousin, Angela Hernandez, holds electric bulbs on page 212, and photos of her family are on pages 52, 86, 136, and 146. Thank you Angela! Third cousin, Isaac Jones, shows the nil effects of a fireworks sparkler on page 152, as his father Terrence illustrated in the part-opening photo on heat in earlier editions of *Conceptual Physics*. Another second cousin, Esther Alejandra Gonzales, illustrates Newton's third law on page 57. And dear to all three authors, our late friend Charlie Spiegel is shown on page 274.

Physics professor friends include the following: contributor Ken Ford, who shares his passion between physics and flying on page 255; Tsing Bardin illustrates liquid pressure on page 125; from the Exploratorium in San Francisco are Ron Hipschman freezing water on page 182 and Patty O'Plasma illustrating sound and color on pages 252 and 296; from City College of San Francisco instructors are Fred Cauthen on page 241; Jill Johnsen on page 61; and Shruti Kumar on page 119.

Paul's physics teaching friends listed from the front to the back of the book include the following: Evan Jones illustrates Bernoulli's Principle on page 139; Marshall Ellenstein, the producer of Paul's DVDs and webmaster of Paul's physics screencasts, walks barefoot on broken glass on page 147; David Housden demonstrates Paul's favorite circuit demo on page 209; Fred Myers shows magnetic force on page 224; the late Jean Curtis shows magnetic levitation on page 232; Karen Jo Matsler generates light on page 236; Diane Reindeau demonstrates waves on page 245; Tom Greenslade illustrates wave motion with a slinky on page 246; Bree Barnett Dreyfuss illustrates wave superposition on page 254; Lynda Williams sings her heart out on page 260; Peter Hopkinson displays an impressive mirror antic on page 297; and Chelcie Liu concludes with his novel race tracks in Appendix A.

Paul's dear personal friends include Burl Grey on page 21, who stimulated Paul's love of physics a half century ago, and Howie Brand from college days illustrating impulse and changes in momentum on page 65. Former student Cassy Cosme safely breaks bricks with her bare hand on page 65. Will Maynez shows the airtrack he built for City College of San Francisco (CCSF) on page 70, and burns a peanut on page 164. Bob Miner pushes a wall without doing work on it on page 71. Tenny Lim, former student and now a design engineer for Jet Propulsion Labs, puts energy into her bow on page 72. David Vasquez shows his passion for generating electricity via fuel cells on page 81. David's nephew Carlos Vasquez is colorfully shown on page 284. Duane Ackerman's daughter Charlotte is on page 13. Dan Johnson, from college days, crushes a can with atmospheric pressure on page 143. Doing the same on a larger scale on page 148 are P. O. Zetterberg with Tomas and Barbara Brage. P. O.'s wife, Anette Zetterberg, presents an intriguing thermal expansion question on page 166. Dennis McNelis illustrates thermal radiation on page 174 and, with daughter

Melissa, scaling Earth and Moon on page 742. Another former student, Helen Yan, now an orbit analyst for Lockheed Martin Corporation and part-time CCSF physics instructor, poses with a black and white box on page 175. Hawaii friend Chiu Man Wu, the dad of Andrea who is on page 89, is on page 178. Close friend from teen years, the late Paul Ryan, sweeps his finger through molten lead on page 184. Tim Gardner illustrates induction on page 240. Science author Suzanne Lyons with children Tristan and Simone illustrate complementary colors on page 298. Tammy and Larry Tunison demonstrate radiation safety on page 333. Abby Dijamco produces touching music on page 243.

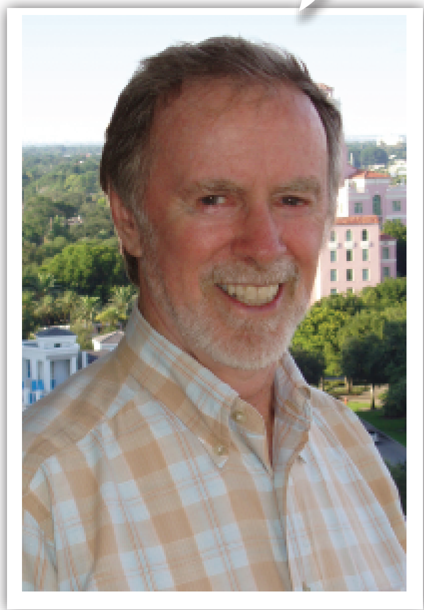
These photographs are of people very dear to the authors, which all the more makes *Conceptual Physical Science* our labor of love.

To the Student

Physical Science is about the rules of the physical world—physics, chemistry, geology, and astronomy. Just as you can't enjoy a ball game, computer game, or party game until you know its rules, so it is with nature. Nature's rules are beautifully elegant and can be neatly described mathematically. That's why many physical science texts are treated as applied mathematics. But too much emphasis on computation misses something essential—*comprehension*—a gut feeling for the concepts. This book is *conceptual,* focusing on concepts in down-to-earth English rather than in mathematical language. You'll see the mathematical structure in frequent equations, but you'll find them *guides to thinking* rather than recipes for computation.

We enjoy physical science, and you will too—because you'll understand it. Just as a person who knows the rules of botany best appreciates plants, and a person who knows the intricacies of music best appreciates music, you'll better appreciate the physical world about you when you learn its rules.

Enjoy your physical science!



Paul G. Hewitt   John Suchocki   Leslie A. Hewitt

To the Instructor

This Sixth Edition of *Conceptual Physical Science* with its important ancillaries provides your students an enjoyable and readable introductory coverage of the physical sciences. As with the previous edition, 28 chapters are divided into four main parts—Physics, Chemistry, Earth Sciences, and Astronomy. We begin with physics, the basic science that provides a foundation for chemistry, which in turn extends to Earth science and astronomy.

For the nonscience student, this book affords a means of viewing nature more perceptively—seeing that a surprisingly few relationships make up its rules, most of which are the laws of physics unambiguously expressed in equation form. The use of equations for problem solving are minimized. Equations in this book are more effectively treated as *guides to thinking*. The symbols in equations are akin to musical notes that guide musicians.

For the science student, this same foundation affords a springboard to other sciences such as biology and health-related fields. For more quantitative students, end-of-chapter material provides ample problem-solving activity. Many of these problems are couched in symbols first—with secondary emphasis on numerical values. All problems nevertheless stress the connections in physics and in chemistry.

Physics begins with static equilibrium so that students can start with forces before studying velocity and acceleration. After success with simple forces, the coverage touches lightly on kinematics—enough preparation for Newton's laws of motion. The pace picks up with the conventional order of mechanics followed by heat, thermodynamics, electricity and magnetism, sound, and light. Physics chapters lead to the realm of the atom—a bridge to chemistry.

The chemistry chapters begin with a look at the submicroscopic world of the atom, which is described in terms of subatomic particles and the periodic table. Students are then introduced to the atomic nucleus and its relevance to radioactivity, nuclear power, as well as astronomy. Subsequent chemistry chapters follow a traditional approach that covers chemical changes, bonding, molecular interactions, and the formation of mixtures. With this foundation students are then set to learn the mechanics of chemical reactions and the behavior of organic compounds. As with previous editions, chemistry is related to the student's familiar world—the fluorine in their toothpaste, the Teflon on frying pans, and the flavors produced by various organic molecules. The environmental aspects of chemistry are also highlighted—from how our drinking water is purified to how atmospheric carbon dioxide influences the pH of rainwater and our oceans.

The Earth science chapters focus on the interconnections between the geosphere, hydrosphere, and atmosphere. Geosphere chapters begin in a traditional sequence—rocks and minerals, plate tectonics, earthquakes, volcanoes, and the processes of erosion and deposition and their influence on landforms. This foundation material is revisited in an examination of Earth over geologic time. A study of Earth's oceans leads to a focus on the interactions between the hydrosphere and atmosphere. Heat transfer and the differences in seawater density across the globe set the stage for discussions of atmospheric and oceanic circulation and Earth's overall climate. Concepts from physics are reexamined in the driving forces of weather. We conclude with an exploration of severe weather adding depth to the study of the atmosphere.

The applications of physics, chemistry, and the Earth sciences applied to other massive bodies in the universe culminate in Part Four—Astronomy. Of all the physical sciences, astronomy and cosmology are arguably undergoing the most rapid development. Many recent discoveries are featured in this edition, illustrating how science is more than a growing body of knowledge; it is an arena in which humans actively and systematically reach out to learn more about our place in the universe.

What's New to This Edition

Conceptual Physical Science, Sixth Edition, retains the pedagogical features developed in earlier editions. Text content is presented in a reader-friendly **narrative** in which the concepts of science are explained in a story-telling fashion with an emphasis on how these concepts relate to the student's everyday world, which is why students find this book so readable. This material has been updated to reflect recent developments, which are most notable in the Earth science and astronomy chapters. Because it is important that the student read the textbook slowly for comprehension, we include the ever-important **CHECKPOINTS** that encourage the student to stop reading periodically to reflect on what they think they have just learned. And, of course, the narrative is tightly integrated with an **art program** featuring photos and illustrations carefully developed over many years based upon the feedback of instructors and students alike.

Perhaps the most significant upgrade is the inclusion of **video tutorials** including **screencasts** created by the authors. For the printed book, students access these by scanning the QR code within the textbook margin using a portable electronic device, such as a smart phone. For the eBook, the student merely clicks on the video icon. If you are looking to "flip" your classroom, please note that the full library of author-created video lessons is available for free at the authors' personal website, ConceptualAcademy.com. We feel that these video lessons are our most recent and important contribution to making physical science correct and understandable. Yet another tool for helping your students come to class prepared, these video lessons nicely complement the chapter material helping to give the students the context they need to read the textbook with greater understanding.

Learning objectives are now placed at the start of each chapter. An **Explain This** question is still beneath each section head—a question the student should only be able to answer after having read the chapter section. Many chapters include updated **boxed essays** where related but optional topics are explored in more detail. Perhaps most important of these are the **Figuring Physical Science** boxes, which walk the student through a mathematical analysis of the concepts presented in the narrative. In the margins are updated **FYI** side notes highlighting applications of the concepts, and **Insights** that are brief and insightful comments identified by an LED light blub.

Significant updates to the content of this edition are as follows: fuel-cell technology coupled with photovoltaic panels in Chapter 3; geothermal heating or cooling of homes in Chapter 8; trans-fats now discussed in Chapter 12; a new subsection on thorium nuclear reactors in Chapter 13; the concept of enthalpy introduced in Chapter 17; updates on global climate change and ocean acidification in Chapters 18 and 24; a major revision of atmospheric moisture in Section 25.1; a new presentation of nebula and discussions of the internal and external structure of the Sun and deeper detail on the non-planetary bodies such as the asteroids, trojans, greeks, hildas, centaurs, and KBO's, with updated images and discussions of comet 67P, Vesta, Ceres, and the Pluto system in Chapter 27; updates on cosmology and the latest on dark matter and dark energy in Chapter 28; and most notably, a new chapter section on Einstein's special theory of relativity that now follows the general relativity section in Chapter 28.

Another important upgrade is further development of the end-of-chapter material, with some 150 new questions added. Existing questions have been reviewed for accuracy and clarity (thank you Bruce Novak!). **Exercises** are now segregated by chapter sections, which should facilitate homework assignments.

As with the previous edition, the end-of-chapter material is organized around Bloom's taxonomy of learning as follows:

Summary of Terms (Knowledge)

The definitions have been edited to match, word-for-word, the definitions given within the chapter. These key terms are now listed alphabetically so that they appear as a mini-glossary for the chapter.

Reading Check Questions (Comprehension)

These questions frame the important ideas of each section in the chapter. They are meant solely for a review of reading comprehension, not to challenge student intellect. They are simple questions and all answers are easily looked up in the chapter.

Activities (Hands-On Application)

The *Activities* is a set of easy-to-perform hands-on activities designed to help students experience the physical science concepts for themselves on their own or with others.

Plug and Chug (Formula Familiarization)

One-step insertion of quantities into provided mathematical formulas allows the student to perform quick and non-intimidating calculations.

Think and Solve (Mathematical Application)

Think and Solve questions blend simple mathematics with concepts. They allow students to apply the problem-solving techniques featured in the Figuring Physical Science boxes that appear in many chapters.

Think and Rank (Analysis)

Think and Rank questions ask students to analyze trends based upon their understanding of concepts. Critical thinking is called for.

Exercises (Synthesis)

Exercises, by a notch or two, are the more challenging questions of each chapter. Many require critical thinking while others are designed to prompt the application of science to everyday situations. All students wanting to perform well on exams should be directed to the *Exercises* because they directly assess student understanding.

Discussion Questions (Evaluation)

Discussion Questions provide students the opportunity to apply the concepts of physical science to real-life situations, such as whether a cup of hot coffee served to you in a restaurant cools faster when cream is added promptly or a few minutes later. Other *Discussion Questions* allow students to present their educated opinions on a number of science-related hot topics, such as the appearance of pharmaceuticals in drinking water or whether it would be a good idea to enhance the ocean's ability to absorb carbon dioxide by adding powdered iron.

Readiness Assurance Test (RAT)

Each chapter review concludes with a set of 10 multiple choice questions for self-assessment. Students are advised to study further if they score less than 7 correct answers.

Students can find the solutions to the odd-numbered end-of-chapter questions in the back of the textbook.

Acknowledgments

We are enormously grateful to outstanding teachers Bruce Novak and Dean Baird to whom this edition is dedicated. Their love of students is reflected in their contributions of new and insightful information, contributing to this being the best edition of *Conceptual Physical Science* ever.

We remain grateful to Ken Ford for extensive feedback, from previous editions to the present. While tweaking parts of this edition, Ken also wrote his own book, *Building the H-Bomb, a Personal History*. Congratulations Ken! We are also grateful to Lillian Lee Hewitt for extensive editorial help in both the book and its ancillaries. That gratefulness includes John's wife Tracy Suchocki for assisting with the chemistry ancillaries, particularly with the new chemistry and astronomy *Practice Pages*. We thank Fe Davis, Angela Hernandez, and Bob Hulsman for their photos. We are grateful to Scotty Graham for physics suggestions, to Evan Jones and John Sperry for their contributions to *Think and Solve* problems, and to Brad Butler for problem suggestions.

For physics input to previous editions we remain grateful to Tsing Bardin, Howie Brand, George Curtis, Alan Davis, Paul Doherty, Marshall Ellenstein, John Hubisz, Marilyn Hromatko, Dan Johnson, Tenny Lim, Iain McInnes, Fred Myers, Mona Nasser, Diane Reindeau, Chuck Stone, Larry Weinstein, Jeff Wetherhold, David Williamson, Phil Wolf, P. O. Zetterberg, and Dean Zollman.

For development of chemistry chapters, thanks go to the following professors for their reviews: Adedoyin Adeyiga, Linda Bates, Dave Benson, John Bonte, Emily Borda, Charles Carraher, Natashe Cleveland, Robin DeRoo, Sara Devo, Andy Frazer, Kenneth French, Marcia Gillette, Chu-Ngi Ho, Frank Lambert, Chris Maloney, Christopher Merli, Barbara Pappas, Michelle Paustenbaugh, Daniel Predecki, Britt Price, Jeremy Ramsey, Rejendra Ravel, Kathryn Rust, William Scott, Anne Marie Sokol, Jason Vohs, Bob Widing, and David Yates.

For Earth science feedback and contributions we remain thankful to Mary Brown, Ann Bykerk-Kauffman, Oswaldo Garcia, Newell Garfield, Karen Grove, Trayle Kulshan, Jan Null, Katryn Weiss, Lisa White, and Mike Young. Special appreciation goes to Bob Abrams for his assistance with the Earth science material; and to Megan and Emily Abrams for their inspiration, their curiosity, and their new found appreciation of hiking and rock collecting.

For the astronomy chapters we extend our gratitude once again to Bruce Novak who painstakingly reviewed every sentence for both accuracy and clarity. He was assisted by astronomy professor Mark Petricone to whom we also extend our thanks. We are grateful to Megan Donahue, Nicholas Schneider, and Mark Voit for permission to use many of the graphics that appear in their textbook *The Cosmic Perspective*. A special thanks to Jeffery Bennett and Chuck Stone for their review of the astronomy videos. Also, for reviews of the astronomy chapters we remain grateful to the late Richard Crowe, Bjorn Davidson, Stacy McGaugh, Michelle Mizuno-Wiedner, John O'Meara, Neil deGrasse Tyson, Joe Wesney, Lynda Williams, and Erick Zackrisson.

Special thanks to the dedicated talented staff at Pearson particularly Jeanne Zalesky, Martha Steele, Mary Ripley, Kate Brayton, and Mark Ong. To Rose Kernan and the production team at Cenveo we extend a heartfelt thanks for such a beautiful job in composing the pages of this latest edition. We are especially thankful to our long time publisher and friend Jim Smith for his generous support that has made our work possible.

Instructional Package

Conceptual Physical Science, sixth edition, provides an integrated teaching and learning package of support material for students and instructors.

Name of Supplement	Available in Print	Available Online	Instructor or Student Supplement	Description
MasteringPhysics® with Pearson eText (ISBN 013407999X)		✓	Supplement for Instructors and Students	This product features all of the resources of MasteringPhysics in addition to the **NEW! Pearson eText 2.0.** Now available on smartphones and tablets, Pearson eText 2.0 comprises the full text, including videos and other rich media. Students can configure reading settings, including resizeable type and night-reading mode, take notes, and highlight, bookmark, and search the text.
Instructor Manual for Conceptual Physical Science (ISBN 0134092007)		✓	Supplement for Instructors	This manual allows for a variety of course designs, with many lecture ideas and topics not treated in the textbook, teaching tips for "flipping" your class, and solutions to all the end-of-chapter material.
Conceptual Physical Science Practice Book (ISBN 0134091396)	✓		Supplement for Students	Expanded for this sixth edition, this resource provides engaging worksheets that guide students in developing concepts, with user-friendly analogies and intriguing situations. A great resource for classroom team-based learning.
TestGen Test Bank for Conceptual Physical Science (ISBN 0134091426)		✓	Supplement for Instructors	Written solely by the authors, the *Test Bank* has more than 2500 multiple-choice questions and short-answer and essay questions categorized by difficulty level. You can edit and add questions, and create multiple test versions. Questions have been vetted for clarity and to ensure they match the text's content.
Laboratory Manual for Conceptual Physical Science (ISBN 0134091418)	✓		Supplement for Students	Written by Dean Baird with input from the authors, this manual provides a range of activities similar to the activities in the textbook and interesting laboratory experiments that guide students to experience and quantify phenomena Answers to the lab manual questions are in the *Instructor Manual.*
Instructor's Resource DVD for *Conceptual Physical Science* (ISBN 0134091434)	✓	✓	Supplement for Instructors	This cross-platform DVD includes all images from the book in JPEG format; interactive figures™ and videos; author-written PowerPoint® lecture outlines and clicker questions; and Hewitt's acclaimed Next-Time Questions in PDF format.
Problem Solving for Conceptual Physics (ISBN 032166258X)	✓		Supplement for Students	This text provides problem-solving techniques in algebraic physics.

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PROLOGUE

The Nature of Science

LITTLE GRACIE is intrigued to learn that Earth's atmosphere acts as a lens that bends the red light of sunsets and sunrises all around Earth onto the Moon during a lunar eclipse, making it reddish instead of dark. Gracie loves science, which after all is the product of human curiosity about how the world works—an organized body of knowledge that describes the order within nature and the causes of that order. *Science* is an ongoing human activity that represents the collective efforts, findings, and wisdom of the human race, an activity that is dedicated to gathering knowledge about the world and to organizing and condensing it into testable laws and theories. In our study of science, we are learning about the rules of nature—how one thing is connected to another and how patterns underlie all we see in our surroundings. Any activity, whether a sports game, a computer game, or the game of life, is meaningful only when we understand its rules. Learning about nature's rules is Relevant with a capital R!

We will see in this text that science is much more than a body of knowledge. Science is a way of thinking.

A Brief History of Advances in Science

EXPLAIN THIS How did the advent of the printing press affect the growth of science?

Science made great headway in Greece in the 4th and 3rd centuries BC and spread throughout the Mediterranean world. Scientific advance came to a near halt in Europe when the Roman Empire fell in the 5th century AD. Barbarian hordes destroyed almost everything in their paths as they overran Europe. Reason gave way to religion, which ushered in what came to be known as the Dark Ages. During this time, the Chinese and Polynesians were charting the stars and the planets. Before the advent of Islam, Arab nations developed mathematics and learned about the production of glass, paper, metals, and various chemicals. Greek science was reintroduced to Europe by Islamic influences that penetrated into Spain during the 10th, 11th, and 12th centuries. Universities emerged in Europe in the 13th century, and the introduction of gunpowder changed the social and political structure of Europe in the 14th century. The 15th century saw art and science beautifully blended by Leonardo da Vinci. Scientific thought was furthered in the 16th century with the advent of the printing press.

The 16th-century Polish astronomer Nicolaus Copernicus caused great controversy when he published a book proposing that the Sun is stationary and that Earth revolves around the Sun. These ideas conflicted with the popular view that Earth was the center of the universe. They also conflicted with Church teachings and were banned for 200 years. The Italian physicist Galileo Galilei was arrested for popularizing the Copernican theory and for his other contributions to scientific thought. Yet a century later, those who advocated Copernican ideas were accepted.

These cycles occur age after age. In the early 1800s, geologists met with violent condemnation because they differed with the account of creation in the book of Genesis. Later in the same century, geology was accepted, but theories of evolution were condemned and the teaching of them was forbidden. Every age has its groups of intellectual rebels who are scoffed at, condemned, and sometimes even persecuted at the time but who later seem beneficial and often essential to the elevation of human conditions. "At every crossway on the road that leads to the future, each progressive spirit is opposed by a thousand men appointed to guard the past."*

Science is a way of knowing about the world and making sense of it.

fyi

- In pre-Copernican times the Sun and Moon were viewed as planets. Their planetary status was removed when Copernicus substituted the Sun for Earth's central position. Only then was Earth regarded as a planet among others. More than 200 years later, in 1781, telescope observers added Uranus to the list of planets. Neptune was added in 1846. Pluto was added in 1930—and removed in 2006.

Mathematics and Conceptual Physical Science

EXPLAIN THIS What is meant by "Equations are guides to thinking"?

Science and human conditions advanced dramatically after science and mathematics became integrated some four centuries ago. When the ideas of science are expressed in mathematical terms, they are unambiguous. The equations of science provide compact expressions of relationships between concepts. They don't have the multiple meanings that so often confuse the discussion of ideas expressed in common language. When findings in nature are expressed mathematically, they are easier to verify or to disprove by experiment. The mathematical structure of physics is evident in the many equations you will encounter throughout this text. The equations are guides to thinking that show

Scientists have a deep-seated need to know Why? and What if? Mathematics is foremost in their tool kits for tackling these questions.

* From Count Maurice Maeterlinck's "Our Social Duty."

the connections between concepts in nature. The methods of mathematics and experimentation led to enormous success in science.*

Scientific Methods

EXPLAIN THIS What else besides the common scientific method advances science?

There is no *one* scientific method. But there are common features in the way scientists do their work. Although no cookbook description of the **scientific method** is really adequate, some or all of the following steps are likely to be found in the way most scientists carry out their work.

1. *Observe.* Closely observe the physical world around you. Recognize a question or a puzzle—such as an unexplained observation.
2. *Question.* Make an educated guess—a **hypothesis**—to answer the question.
3. *Predict.* Predict consequences that can be observed if the hypothesis is correct. The consequences should be *absent* if the hypothesis is not correct.
4. *Test predictions.* Do experiments to see whether the consequences you predicted are present.
5. *Draw a conclusion.* Formulate the simplest general rule that organizes the hypothesis, predicted effects, and experimental findings.

> Science is a way to teach how something gets to be known, what is not known, to what extent things are known (for nothing is known absolutely), how to handle doubt and uncertainty, what the rules of evidence are, how to think about things so that judgments can be made, and how to distinguish truth from fraud and from show.
> —Richard Feynman

Although these steps are appealing, much progress in science has come from trial and error, experimentation without hypotheses, or just plain accidental discovery by a well-prepared mind. The success of science rests more on an attitude common to scientists than on a particular method. This attitude is one of inquiry, experimentation, and humility—that is, a willingness to admit error.

The Scientific Attitude

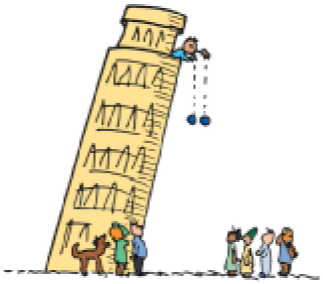
EXPLAIN THIS Why does falsifying information discredit a scientist but not a lawyer?

It is common to think of a fact as something that is unchanging and absolute. But in science, a **fact** is generally a close agreement by competent observers who make a series of observations about the same phenomenon. For example, although it was once a fact that the universe is unchanging and permanent, today it is a fact that the universe is expanding and evolving. A scientific hypothesis, on the other hand, is an educated guess that is only presumed to be factual until supported by experiment. When a hypothesis has been tested over and over again and has not been contradicted, it may become known as a **law** or *principle*.

If a scientist finds evidence that contradicts a hypothesis, law, or principle, the scientific spirit requires that the hypothesis be changed or abandoned (unless the contradicting evidence, upon testing, turns out to be wrong—which sometimes happens). For example, the greatly respected Greek philosopher Aristotle (384–322 BC) claimed that an object falls at a speed proportional to its

> Experiment, not philosophical discussion, decides what is correct in science.

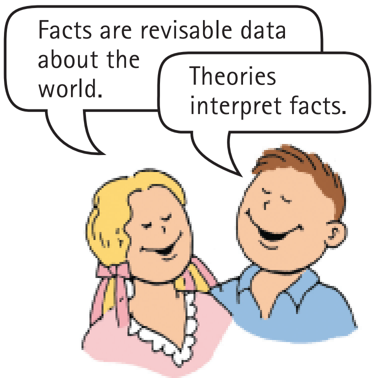
* We distinguish between the mathematical structure of science and the practice of mathematical problem solving—the focus of most nonconceptual courses. Note that there are far fewer mathematical problems than exercises at the ends of the chapters in this text. The focus is on comprehension before computation.



weight. This idea was held to be true for nearly 2000 years because of Aristotle's compelling authority. Galileo allegedly showed the falseness of Aristotle's claim with one experiment—demonstrating that heavy and light objects dropped from the Leaning Tower of Pisa fell at nearly equal speeds. In the scientific spirit, a single verifiable experiment to the contrary outweighs any authority, regardless of reputation or the number of followers or advocates. In modern science, argument by appeal to authority has little value.*

Scientists must accept their experimental findings even when they would like them to be different. They must strive to distinguish between what they see and what they wish to see, for scientists, like most people, have a vast capacity for fooling themselves.** People have always tended to adopt general rules, beliefs, creeds, ideas, and hypotheses without thoroughly questioning their validity and to retain them long after they have been shown to be meaningless, false, or at least questionable. The most widespread assumptions are often the least questioned. Most often, when an idea is adopted, particular attention is given to cases that seem to support it, while cases that seem to refute it are distorted, belittled, or ignored.

Scientists use the word *theory* in a way that differs from its usage in everyday speech. In everyday speech, a theory is no different from a hypothesis—a supposition that has not been verified. A scientific **theory,** on the other hand, is a synthesis of a large body of information that encompasses well-tested and verified hypotheses about certain aspects of the natural world. Physicists, for example, speak of the quark theory of the atomic nucleus, chemists speak of the theory of metallic bonding in metals, and biologists speak of the cell theory.



The theories of science are not fixed; rather, they undergo change. Scientific theories evolve as they go through stages of redefinition and refinement. During the past hundred years, for example, the theory of the atom has been repeatedly refined as new evidence on atomic behavior has been gathered. Similarly, chemists have refined their view of the way molecules bond together, and biologists have refined the cell theory. The refinement of theories is a strength of science, not a weakness. Many people feel that it is a sign of weakness to change their minds. Competent scientists must be experts at changing their minds. They change their minds, however, only when confronted with solid experimental evidence or when a conceptually simpler hypothesis forces them to a new point of view. More important than defending beliefs is improving them. Better hypotheses are made by those who are honest in the face of experimental evidence.

Before a theory is accepted, it must be tested by experiment and make one or more new predictions—different from those made by previous theories.

Away from their profession, scientists are inherently no more honest or ethical than most other people. But in their profession, they work in an arena that places a high premium on honesty. The cardinal rule in science is that all hypotheses must be testable—they must be susceptible, at least in principle, to being shown to be *wrong*. Speculations that cannot be tested are regarded as "unscientific." This has the long-run effect of compelling honesty—findings widely publicized among fellow scientists are generally subjected to further testing. Sooner or later, mistakes (and deception) are found out; wishful thinking is exposed. A discredited scientist does not get a second chance in the community of scientists. The penalty for fraud is professional excommunication. Honesty, so important to the progress of science, thus becomes a matter of self-interest to scientists. There is relatively little bluffing in a game in which all bets are called. In fields of study where right and wrong are not so easily established, the pressure to be honest is considerably less.

* But appeal to *beauty* has value in science. More than one experimental result in modern times has contradicted an appealing theory that, upon further investigation, proved to be wrong. This has bolstered scientists' faith that the ultimately correct description of nature involves conciseness of expression and economy of concepts—a combination that deserves to be called beautiful.

** In your education it is not enough to be aware that other people may try to fool you; it is more important to be aware of your own tendency to fool yourself.

In science, it is more important to have a means of proving an idea wrong than to have a means of proving it right. This is a major factor that distinguishes science from nonscience. At first this may seem strange, for when we wonder about most things, we concern ourselves with ways of finding out whether they are true. Scientific hypotheses are different. In fact, if you want to distinguish whether a hypothesis is scientific, look to see whether there is a test for proving it wrong. If there is no test for its possible wrongness, then the hypothesis is not scientific. Albert Einstein put it well when he stated, "No number of experiments can prove me right; a single experiment can prove me wrong."

Consider the biologist Charles Darwin's hypothesis that life forms evolve from simpler to more complex forms. This could be proved wrong if paleontologists were to find that more complex forms of life appeared before their simpler counterparts. Einstein hypothesized that light is bent by gravity. This might be proved wrong if starlight that grazed the Sun and could be seen during a solar eclipse were undeflected from its normal path. As it turns out, less complex life forms are found to precede their more complex counterparts and starlight is found to bend as it passes close to the Sun, observations that support the claims. If and when a hypothesis or scientific claim is confirmed, it is regarded as useful and as a stepping-stone to additional knowledge.

Consider the hypothesis "The alignment of planets in the sky determines the best time for making decisions." Many people believe it, but this hypothesis is not scientific. It cannot be proved wrong, nor can it be proved right. It is *speculation*. Likewise, the hypothesis "Intelligent life exists on other planets somewhere in the universe" is not scientific. Although it can be proved correct by the verification of a single instance of intelligent life existing elsewhere in the universe, there is no way to prove it wrong if no intelligent life is ever found. If we searched the far reaches of the universe for eons and found no life, even that would not proved that it doesn't exist "around the next corner." A hypothesis that is capable of being prove right but not capable of being proved wrong is not a scientific hypothesis. Many such statements are quite reasonable and useful, but they lie outside the domain of science.

The essence of science is expressed in two questions: How would we know? What evidence would prove this idea wrong? Assertions without evidence are unscientific and can be dismissed without evidence.

We each need a *knowledge filter* to tell the difference between what is true and what only pretends to be true. The best knowledge filter ever invented for explaining the physical world is science.

CHECKPOINT

Which of these statements is a scientific hypothesis?

(a) Atoms are the smallest particles of matter that exist.

(b) Space is permeated with an essence that is undetectable.

(c) Albert Einstein was the greatest physicist of the 20th century.

Was this your answer?

Only statement (a) is scientific, because there is a test for falseness. The statement not only is *capable* of being proved wrong, but *has* been proved wrong. Statement (b) has no test for possible wrongness and is therefore unscientific. Likewise for any principle or concept for which there is no means, procedure, or test whereby it can be shown to be wrong (if it is wrong). Some pseudoscientists and other pretenders to knowledge will not even consider a test for the possible wrongness of their statements. Statement (c) is an assertion that has no test for possible wrongness. If Einstein was not the greatest physicist, how could we know? Note that because the name Einstein is generally held in high esteem, it is a favorite of pseudoscientists. So we should not be surprised that the name of Einstein, like that of Jesus or of any other highly respected person, is cited often by charlatans who wish to accrue respect to themselves and their points of view. In all fields, it is prudent to be skeptical of those who wish to credit themselves by calling upon the authority of others.

Science Has Limitations

EXPLAIN THIS How do the domains of science and the supernatural differ?

Science deals only with hypotheses that are testable. Its domain is therefore restricted to the observable natural world. Although scientific methods can be used to debunk various paranormal claims, they have no way of accounting for testimonies involving the supernatural. The term *supernatural* literally means "above nature." Science works within nature, not above it. Likewise, science is unable to answer philosophical questions, such as "What is the purpose of life?" or religious questions, such as "What is the nature of the human spirit?" Even though these questions are valid and may have great importance to us, they rely on subjective personal experience and do not lead to testable hypotheses. They lie outside the realm of science.

SCIENCE AND SOCIETY

Pseudoscience

For a claim to qualify as scientific, it must meet certain standards. For example, the claim must be reproducible by others who have no stake in whether the claim is true or false. The data and subsequent interpretations are open to scrutiny in a social environment where it's okay to have made an honest mistake, but not okay to have been dishonest or deceiving. Claims that are presented as scientific but do not meet these standards are what we call **pseudoscience,** which literally means "fake science." In the realm of pseudoscience, skepticism and tests for possible wrongness are downplayed or flatly ignored.

Examples of pseudoscience abound. Astrology is an ancient belief system that supposes that a person's future is determined by the positions and movements of planets and other celestial bodies. Astrology mimics science in that astrological predictions are based on careful astronomical observations. Yet astrology is not a science because there is no validity to the claim that the positions of celestial objects influence the events of a person's life. After all, the gravitational force exerted by celestial bodies on a person is smaller than the gravitational force exerted by objects making up the earthly environment: trees, chairs, other people, bars of soap, and so on. Further, the predictions of astrology are not borne out; there just is no evidence that astrology works.

For more examples of pseudoscience, look to television or the Internet. You can find advertisements for a plethora of pseudoscientific products. Watch out for remedies to ailments such as baldness, obesity, and cancer; for air-purifying mechanisms; and for "germ-fighting" cleaning products in particular. Although many such products operate on solid science, others are pure pseudoscience. Buyer beware!

Humans are very good at denial, which may explain why pseudoscience is such a thriving enterprise. Many pseudoscientists do not recognize their efforts as pseudoscience. A practitioner of "absent healing," for example, may truly believe in her ability to cure people she will never meet except through e-mail and credit card exchanges.

She may even find anecdotal evidence to support her contentions. The *placebo effect,* discussed in Section 8.2, can mask the ineffectiveness of various healing modalities. In terms of the human body, what people believe *will* happen often *can* happen because of the physical connection between the mind and body.

That said, consider the enormous downside of pseudoscientific practices. Today more than 20,000 astrologers are practicing in the United States. Do people listen to these astrologers just for the fun of it? Or do they base important decisions on astrology? You might lose money by listening to pseudoscientific entrepreneurs; worse, you could become ill. Delusional thinking, in general, carries risk.

Meanwhile, the results of science literacy tests given to the general public show that most Americans lack an elementary understanding of basic concepts of science. Some 63% of American adults are unaware that the mass extinction of the dinosaurs occurred long before the first human evolved; 75% do not know that antibiotics kill bacteria but not viruses; 57% do not know that electrons are smaller than atoms. What we find is a rift—a growing divide—between those who have a realistic sense of the capabilities of science and those who do not understand the nature of science and its core concepts, or, worse, feel that scientific knowledge is too complex for them to understand. Science is a powerful method for understanding the physical world, and it is a whole lot more reliable than pseudoscience as a means for bettering the human condition.

Science, Art, and Religion

EXPLAIN THIS Why is the statement "Never question what this book says" outside the domain of science?

The search for a deeper understanding of the world around us has taken different forms, including science, art, and religion. Science is a system by which we discover and record physical phenomena and think about possible explanations for such phenomena. The arts are concerned with personal interpretation and creative expression. Religion addresses the source, purpose, and meaning of it all. Simply put, science asks *how,* art asks *who,* and religion asks *why*.

Science and the arts have certain things in common. In the art of literature, we find out about what is possible in human experience. We can learn about emotions such as rage and love, even if we haven't yet experienced them. The arts describe these experiences and suggest what may be possible for us. Similarly, a knowledge of science tells us what is possible in nature. Scientific knowledge helps us predict possibilities in nature even before we experience them. It provides us with a way of connecting things, of seeing relationships between and among them, and of making sense of the great variety of natural events around us. While art broadens our understanding of ourselves, science broadens our understanding of our environment.

Art is about cosmic beauty. Science is about cosmic order. Religion is about cosmic purpose.

Science and religion have similarities also. For example, both are motivated by curiosity for the natural. Both have great impact on society. Science, for example, leads to useful technological innovations, and religion provides a foothold for many social services. Science and religion, however, are basically different. Science is concerned with understanding the physical universe, while many religions are concerned with faith in, and the worship of, a supreme being and with the creation of human community—not the practice of science. While scientific truth is a matter of public scrutiny, religion is a deeply personal matter. In these respects, science and religion are as different as apples and oranges and do not contradict each other. Science, art, and religion can work very well together, which is why we should never feel forced into choosing one over the other.

When we study the nature of light later in this book, we treat light first as a wave and then as a particle. At first, waves and particles may appear contradictory. You might believe that light can be only one or the other, and that you must choose between them. What scientists have discovered, however, is that light waves and light particles *complement* each other, and that when these two ideas are taken together, they provide a deeper understanding of light. In a similar way, it is mainly people who are either uninformed or misinformed about the deeper natures of both science and religion who feel that they must choose between believing in religion and believing in science. Unless one has a shallow understanding of either or both, there is no contradiction between being religious in one's belief system and being scientific in one's understanding of the natural world.*

A truly educated person is knowledgeable in both the arts and the sciences.

Many people are troubled about not knowing the answers to religious and philosophical questions. Some avoid uncertainty by uncritically accepting almost any comforting answer. An important message in science, however, is that uncertainty is acceptable. For example, if you study quantum physics you'll learn that it is not possible to know with certainty both the momentum and the position of an electron in an atom. The more you know about one, the less

* Of course, this does not apply to certain religious extremists who steadfastly assert that one cannot embrace both science and their brand of religion.

> The belief that there is only one truth and that oneself is in possession of it seems to me the deepest root of all the evil that is in the world.
> —Max Born

you can know about the other. Uncertainty is a part of the scientific process. It's okay not to know the answers to fundamental questions. Why are apples gravitationally attracted to Earth? Why do electrons repel one another? Why do magnets interact with other magnets? Why does energy have mass? At the deepest level, scientists don't know the answers to these questions—at least not yet. We know a lot about where we are, but nothing really about *why* we are. It's okay not to know the answers to such religious questions. Given a choice between a closed mind with comforting answers and an open and exploring mind without answers, most scientists choose the latter. Scientists in general are comfortable with not knowing.

CHECKPOINT

Which of the following activities involves the utmost human expression of passion, talent, and intelligence: (a) painting and sculpture, (b) literature, (c) music, (d) religion, (e) science?

Was this your answer?

All of them. In this text, we focus on science, which is an enchanting human activity shared by a wide variety of people. With present-day tools and know-how, scientists are reaching further and finding out more about themselves and their environment than people in the past were ever able to do. The more you know about science, the more passionate you feel toward your surroundings. There is science in everything you see, hear, smell, taste, and touch!

Technology—The Practical Use of Science

EXPLAIN THIS Who thinks of an idea, who develops it, and who uses it?

Science and technology are also different from each other. Science is concerned with gathering knowledge and organizing it. Technology lets humans use that knowledge for practical purposes, and it provides the instruments scientists need to conduct their investigations.

Technology is a double-edged sword. It can be both helpful and harmful. We have the technology, for example, to extract fossil fuels from the ground and then burn the fossil fuels to produce energy. Energy production from fossil fuels has benefited society in countless ways. On the flip side, the burning of fossil fuels damages the environment. It is tempting to blame technology itself for such problems as pollution, resource depletion, and even overpopulation. These problems, however, are not the fault of technology any more than a stabbing is the fault of the knife. It is humans who use the technology, and humans who are responsible for how it is used.

Remarkably, we already possess the technology to solve many environmental problems. The 21st century will probably see a switch from fossil fuels to more sustainable energy sources. We recycle waste products in new and better ways. In some parts of the world, progress is being made toward limiting human population growth, a serious threat that worsens almost every problem faced by humans today. Difficulty in solving today's problems results more from social inertia than from failing technology. Technology is our tool. What we do with this tool is up to us. The promise of technology is a cleaner and healthier world. Wise applications of technology *can* improve conditions on planet Earth.

RISK ASSESSMENT

The numerous benefits of technology are paired with risks. X-rays, for example, continue to be used for medical diagnosis despite their potential for causing cancer. But when the risks of a technology are perceived to outweigh its benefits, it should be used very sparingly or not at all.

Risk can vary for different groups. Aspirin is useful for adults, but for young children it can cause a potentially lethal condition known as *Reye's syndrome*. Dumping raw sewage into the local river may pose little risk for a town located upstream, but for towns downstream the untreated sewage is a health hazard. Similarly, storing radioactive wastes underground may pose little risk for us today, but for future generations the risks of such storage are greater if there is leakage into groundwater. Technologies involving different risks for different people, as well as differing benefits, raise questions that are often hotly debated. Which medications should be sold to the general public over the counter and how should they be labeled? Should food be irradiated in order to put an end to food poisoning, which kills more than 5000 Americans each year? The risks to all members of society must be considered when public policies are decided.

The risks of technology are not always immediately apparent. No one fully realized the dangers of combustion products when petroleum was selected as the fuel of choice for automobiles early in the last century. From the hindsight of 20/20 vision, alcohols from biomass would have been a superior choice environmentally, but they were banned by the prohibition movements of the day.

Because we are now more aware of the environmental costs of fossil-fuel combustion, biomass fuels are making a slow comeback. An awareness of both the short-term risks and the long-term risks of a technology is crucial.

People seem to have a hard time accepting the impossibility of zero risk. Airplanes cannot be made perfectly safe. Processed foods cannot be rendered completely free of toxicity, for all foods are toxic to some degree. You cannot go to the beach without risking skin cancer, no matter how much sunscreen you apply. You cannot avoid radioactivity, for it's in the air you breathe and the foods you eat, and it has been that way since before humans first walked on Earth. Even the cleanest rain contains radioactive carbon-14, as do our bodies. Between each heartbeat in each human body, there have always been about 10,000 naturally occurring radioactive decays. You might hide yourself in the hills, eat the most natural foods, practice obsessive hygiene, and still die from cancer caused by the radioactivity emanating from your own body. The probability of eventual death is 100%. Nobody is exempt.

Science helps determine the most probable. As the tools of science improve, the assessment of the most probable gets closer to being on target. Acceptance of risk, on the other hand, is a societal issue. Making zero risk a societal goal is not only impractical but also selfish. Any society trying to implement a policy of zero risk will consume its present and future economic resources. Isn't it more noble to accept nonzero risk and minimize risk as much as possible within the limits of practicality? A society that accepts no risks receives no benefits.

The Physical Sciences: Physics, Chemistry, Earth Science, and Astronomy

EXPLAIN THIS Why is physics more fundamental than the other sciences?

Science is the present-day equivalent of what used to be called *natural philosophy*. Natural philosophy was the study of unanswered questions about nature. As the answers were found, they became part of what is now called science. The study of science today branches into the study of living things and nonliving things: the life sciences and the physical sciences. The life sciences branch into such areas as molecular biology, microbiology, and ecology. The *physical sciences* branch into such areas as physics, chemistry, the Earth sciences, and astronomy.

A few words of explanation about each of the major divisions of science: Physics is the study of such concepts as motion, force, energy, matter, heat, sound, light, and the components of atoms. Chemistry builds on physics by