

Conceptual
**Physical
Science**

Sixth Edition

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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—TK—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*

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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 Hawaii friend Andrea Wu 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, 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 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 Minor 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 89. 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 opens Part One, 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.

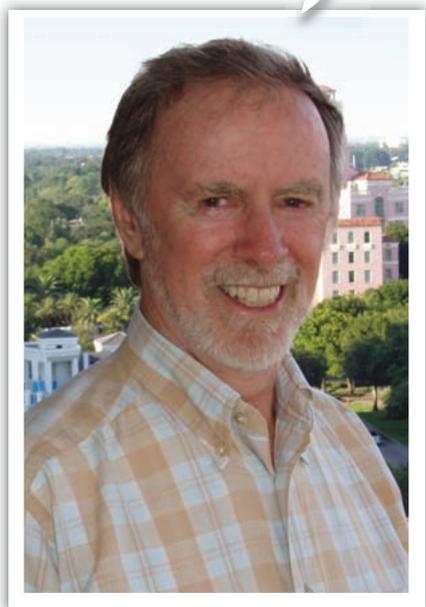
These photographs are of people very dear to the authors, which all the more makes *Conceptual Physical Science* our labor of love.

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 Suckale



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 Wesley, 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 resizable type and night-reading mode, take notes, and highlight, bookmark, and search the text.
<i>Instructor Manual for Conceptual Physical Science</i> (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.
<i>Conceptual Physical Science Practice Book</i> (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.
<i>TestGen Test Bank for Conceptual Physical Science</i> (ISBN 0134091426)		✓	Supplement for Instructors	Written solely by the authors, the <i>Test Bank</i> 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.
<i>Laboratory Manual for Conceptual Physical Science</i> (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 <i>Instructor Manual</i> .
Instructor’s Resource DVD for <i>Conceptual Physical Science</i> (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.
<i>Problem Solving for Conceptual Physics</i> (ISBN 032166258X)	✓		Supplement for Students	This text provides problem-solving techniques in algebraic physics.

