Second Edition

University Physics with Modern Physics

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Michigan State University

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Michigan State University

McGraw Hill
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Brief Contents

About the Authors

Wolfgang Bauer was born in Germany and obtained his Ph.D. in theoretical nuclear physics from the University of Giessen in 1987. After a post-doctoral fellowship at the California Institute of Technology, he joined the faculty at Michigan State University in 1988, with a dual appointment at the National Superconducting Cyclotron Laboratory (NSCL). He has worked on a large variety of topics in theoretical and computational physics, from high-temperature superconductivity to supernova explosions, but has been especially interested in relativistic nuclear collisions. He is probably best known for his work on phase transitions of nuclear matter in heavy ion collisions. In recent years, Dr. Bauer has focused much of his research and teaching on issues concerning energy, including fossil fuel resources, ways to use energy more efficiently, and, in particular, alternative and carbon-neutral energy resources. In 2009, he founded the Institute for Cyber-Enabled Research and served as its first director until 2013. He presently serves as chairperson of the Department of Physics and Astronomy and is a University Distinguished Professor at Michigan State University.

Gary D. Westfall started his career at the Center for Nuclear Studies at the University of Texas at Austin, where he completed his Ph.D. in experimental nuclear physics in 1975. From there he went to Lawrence Berkeley National Laboratory (LBNL) in Berkeley, California, to conduct his post-doctoral work in high-energy nuclear physics and then stayed on as a staff scientist. While he was at LBNL, Dr. Westfall became internationally known for his work on the nuclear fireball model and the use of fragmentation to produce nuclei far from stability. In 1981, Dr. Westfall joined the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU) as a research professor; there he conceived, constructed, and ran the MSU 4π Detector. His research using the 4π Detector produced information concerning the response of nuclear matter as it is compressed in a supernova collapse. In 1987, Dr. Westfall joined the Department of Physics and Astronomy at MSU while continuing to carry out his research at NSCL. In 1994, Dr. Westfall joined the STAR Collaboration, which is carrying out experiments at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory on Long Island, New York. In 2003, he was named University Distinguished Professor at Michigan State University.

The Westfall/Bauer Partnership Drs. Bauer and Westfall have collaborated on nuclear physics research and on physics education research for more than two decades. The partnership started in 1988, when both authors were speaking at the same conference and decided to go downhill skiing together after the session. On this occasion, Westfall recruited Bauer to join the faculty at Michigan State University (in part by threatening to push him off the ski lift if he declined). They obtained NSF funding to develop novel teaching and laboratory techniques, authored multimedia physics CDs for their students at the Lyman Briggs School, and co-authored a textbook on CD-ROM, called *cliXX Physik*. In 1992, they became early adopters of the Internet for teaching and learning by developing the first version of their online homework system. In subsequent years, they were instrumental in creating the Learning*Online* Network with CAPA, which is now used at more than 70 universities and colleges in the United States and around the world. Since 2008, Bauer and Westfall have been part of a team of instructors, engineers, and physicists, who investigate the use of peer-assisted learning in the introductory physics curriculum. This project has received funding from the NSF STEM Talent Expansion Program, and its best practices have been incorporated into this textbook.

Dedication This book is dedicated to our families. Without their patience, encouragement, and support, we could never have completed it.

A Note from the Authors

We are excited to introduce the second edition of our textbook, *University Physics*. Physics is a thriving science, alive with intellectual challenge and presenting innumerable research problems on topics ranging from the largest galaxies to the smallest subatomic particles. Physicists have managed to bring understanding, order, consistency, and predictability to our universe and will continue that endeavor into the exciting future.

However, when we open most current introductory physics textbooks, we find that a different story is being told. Physics is painted as a completed science in which the major advances happened at the time of Newton, or perhaps early in the 20th century. Only toward the end of the standard textbooks is "modern" physics covered, and even that coverage often includes only discoveries made through the 1960s.

Our main motivation in writing this book is to change this perception by weaving exciting, contemporary physics throughout the text. Physics is an amazingly dynamic discipline—continuously on the verge of new discoveries and life-changing applications. In order to help students see this, we need to tell the full, absorbing story of our science by integrating contemporary physics into the first-year calculus-based course. Even the very first semester offers many opportunities to do this by weaving recent results from nonlinear dynamics, chaos, complexity, and high-energy physics research into the introductory curriculum. Because we are actively carrying out research in these fields, we know that many of the cutting-edge results are accessible in their essence to the first-year student.

Recent results involving renewable energy, the environment, engineering, medicine, and technology show physics as an exciting, thriving, and intellectually alive subject motivating students, invigorating classrooms, and making the instructor's job easier and more enjoyable. In particular, we believe that talking about the broad topic of energy provides a great opening gambit to capture students' interest. Concepts of energy sources (fossil, renewable, nuclear, and so forth), energy efficiency, energy storage, alternative energy sources, and environmental effects of energy supply choices (global warming and ocean acidification, for example) are very much accessible on the introductory physics level. We find that discussions of energy spark our students' interest like no other current topic, and we have addressed different aspects of energy throughout our book.

In addition to being exposed to the exciting world of physics, students benefit greatly from gaining the ability to **problem solve and think logically about a situation.** Physics is based on a core set of ideas that is fundamental to all of science. We acknowledge this and provide a useful problem-solving method (outlined in Chapter 1) which is used throughout the entire book. This problem-solving method involves a multistep format that we have developed with students in our classes. But mastery of concepts also involves actively applying them. To this end, we have asked more than a dozen contributors from some of the leading universities across the country to share their best work in the end-of-chapter exercises. New to this edition are approximately 400 multi-version exercises, which allow students to address the same problem from different perspectives.

In 2012, the National Research Council published a framework for K-12 science education, which covers the essential science and engineering practices, the concepts that have application across fields, and the core ideas in four disciplinary areas (in physics, these are matter and its interactions, motion and stability, energy, and waves and their applications in information transfer). We have structured the second edition of this textbook to tie the undergraduate physics experience to this framework and have provided concept checks and self-test opportunities in each chapter.

With all of this in mind, along with the desire to write a captivating textbook, we have created what we hope will be a tool to engage students' imaginations and to better prepare them for future courses in their chosen fields (admittedly, hoping we can convert at least a few students to physics majors along the way). Having feedback from more than 400 people, including a board of advisors, several contributors, manuscript reviewers, and focus group participants, assisted greatly in this enormous undertaking, as did field testing our ideas with approximately 6000 students in our introductory physics classes at Michigan State University. We thank you all!

—Wolfgang Bauer and Gary D. Westfall

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