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College Phys-ics

For AP® Courses

College Physics for AP® Courses

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OpenStax

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Table of Contents

PREFACE

Welcome to *College Physics for AP® Courses*, an OpenStax resource. This textbook was written to increase student access to high-quality learning materials, maintaining highest standards of academic rigor at little to no cost.

About OpenStax

OpenStax is a nonprofit based at Rice University, and it's our mission to improve student access to education. Our first openly licensed college textbook was published in 2012, and our library has since scaled to over 25 books for college and AP® courses used by hundreds of thousands of students. Our adaptive learning technology, designed to improve learning outcomes through personalized educational paths, is being piloted in college courses throughout the country. Through our partnerships with philanthropic foundations and our alliance with other educational resource organizations, OpenStax is breaking down the most common barriers to learning and empowering students and instructors to succeed.

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Format

You can access this textbook for free in web view or PDF through openstax.org, and in low-cost print and iBooks editions.

About *College Physics for AP® Courses*

College Physics for AP® Courses is designed to engage students in their exploration of physics and help them apply these concepts to the Advanced Placement® test. Because physics is integral to modern technology and other sciences, the book also includes content that goes beyond the scope of the AP® course to further student understanding. The AP® Connection in each chapter directs students to the material they should focus on for the AP® exam, and what content — although interesting — is not necessarily part of the AP® curriculum. This book is Learning List-approved for AP® Physics courses.

Coverage, Scope, and Alignment to the AP® Curriculum

The current AP® Physics curriculum framework outlines the two full-year physics courses AP® Physics 1: Algebra-Based and AP® Physics 2: Algebra-Based. These two courses replaced the one-year AP® Physics B course, which over the years had become a fast-paced survey of physics facts and formulas that did not provide in-depth conceptual understanding of major physics ideas and the connections between them.

AP® Physics 1 and 2 courses focus on the big ideas typically included in the first and second semesters of an algebra-based, introductory college-level physics course, providing students with the essential knowledge and skills required to support future advanced course work in physics. The AP® Physics 1 curriculum includes mechanics, mechanical waves, sound, and electrostatics. The AP® Physics 2 curriculum focuses on thermodynamics, fluid statics, dynamics, electromagnetism, geometric and physical optics, quantum physics, atomic physics, and nuclear physics. Seven unifying themes of physics called the Big Ideas each include three to seven enduring understandings (EU), which are themselves composed of essential knowledge (EK) that provides details and context for students as they explore physics.

AP® science practices emphasize inquiry-based learning and development of critical thinking and reasoning skills. Inquiry usually uses a series of steps to gain new knowledge, beginning with an observation and following with a hypothesis to explain the observation; then experiments are conducted to test the hypothesis, gather results, and draw conclusions from data. The AP® framework has identified seven major science practices, which can be described by short phrases: using representations and models to communicate information and solve problems; using mathematics appropriately; engaging in questioning; planning and implementing data collection strategies; analyzing and evaluating data; justifying scientific explanations; and connecting concepts. The framework's Learning Objectives merge content (EU and EK) with one or more of the seven science practices that students should develop as they prepare for the AP® Physics exam.

College Physics for AP® Courses is based on the OpenStax *College Physics* text, adapted to focus on the AP curriculum's concepts and practices. Each chapter of OpenStax *College Physics for AP® Courses* begins with a *Connection for AP® Courses* introduction that explains how the content in the chapter sections align to the Big Ideas, enduring understandings, and essential knowledge in the AP® framework. This textbook contains a wealth of information, and the *Connection for AP® Courses* sections will help you distill the required AP® content from material that, although interesting, exceeds the scope of an introductory-level course.

Each section opens with the program's learning objectives as well as the AP® learning objectives and science practices addressed. We have also developed *Real World Connections* features and *Applying the Science Practices* features that highlight concepts, examples, and practices in the framework.

Pedagogical Foundation and Features

College Physics for AP® Courses is organized so that topics are introduced conceptually with a steady progression to precise definitions and analytical applications. The analytical, problem-solving aspect is tied back to the conceptual before moving on to another topic. Each introductory chapter, for example, opens with an engaging photograph relevant to the subject of the chapter and interesting applications that are easy for most students to visualize.

- **Connections for AP® Courses** introduce each chapter and explain how its content addresses the AP® curriculum.
- **Worked Examples** Examples start with problems based on real-life situations, then describe a strategy for solving the problem that emphasizes key concepts. The subsequent detailed mathematical solution also includes a follow-up

discussion.
- **Problem-solving Strategies** are presented independently and subsequently appear at crucial points in the text where students can benefit most from them.
- **Misconception Alerts** address common misconceptions that students may bring to class.
- **Take-Home Investigations** provide the opportunity for students to apply or explore what they have learned with a hands-on activity.
- **Real World Connections** highlight important concepts and examples in the AP® framework.
- **Applying the Science Practices** includes activities and challenging questions that engage students while they apply the AP® science practices.
- **Things Great and Small** explains macroscopic phenomena (such as air pressure) with submicroscopic phenomena (such as atoms bouncing off of walls).
- **PhET Explorations** link students to interactive PHeT physics simulations, developed by the University of Colorado, to help them further explore the physics concepts they have learned about in their book module.

Assessment

College Physics for AP® Courses offers a wealth of assessment options, including the following end-of-module problems:

- **Integrated Concept Problems** challenge students to apply both conceptual knowledge and skills to solve a problem.
- **Unreasonable Results** encourage students to solve a problem and then evaluate why the premise or answer to the problem are unrealistic.
- **Construct Your Own Problem** requires students to construct how to solve a particular problem, justify their starting assumptions, show their steps to find the solution to the problem, and finally discuss the meaning of the result.
- **Test Prep for AP® Courses** includes assessment items with the format and rigor found in the AP® exam to help prepare students for the exam.

AP Physics Collection

College Physics for AP® Courses is a part of the AP Physics Collection. The AP Physics Collection is a free, turnkey solution for your AP® Physics course, brought to you through a collaboration between OpenStax and Rice Online Learning. The integrated collection pairs the OpenStax College Physics for AP® Courses text with Concept Trailer videos, instructional videos, problem solution videos, and a correlation guide to help you align all of your content. The instructional videos and problem solution videos were developed by Rice Professor Jason Hafner and AP® Physics teachers Gigi Nevils-Noe and Matt Wilson through Rice Online Learning. You can access all of this free material through the College Physics for AP® Courses page on openstax.org.

Additional Resources

Student and Instructor Resources

We've compiled additional resources for both students and instructors, including Getting Started Guides, an instructor solution manual, and instructional videos. Instructor resources require a verified instructor account, which you can apply for when you log in or create your account on openstax.org. Take advantage of these resources to supplement your OpenStax book.

Partner Resources

OpenStax Partners are our allies in the mission to make high-quality learning materials affordable and accessible to students and instructors everywhere. Their tools integrate seamlessly with our OpenStax titles at a low cost. To access the partner resources for your text, visit your book page on openstax.org.

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To the AP® Physics Student

The fundamental goal of physics is to discover and understand the “laws” that govern observed phenomena in the world around us. Why study physics? If you plan to become a physicist, the answer is obvious—introductory physics provides the foundation for your career; or if you want to become an engineer, physics provides the basis for the engineering principles used to solve applied and practical problems. For example, after the discovery of the photoelectric effect by physicists, engineers developed photocells that are used in solar panels to convert sunlight to electricity. What if you are an aspiring medical doctor? Although the applications of the laws of physics may not be obvious, their understanding is tremendously valuable. Physics is involved in medical diagnostics, such as x-rays, magnetic resonance imaging (MRI), and ultrasonic blood flow measurements. Medical therapy sometimes directly involves physics; cancer radiotherapy uses ionizing radiation. What if you are planning a nonscience career? Learning physics provides you with a well-rounded education and the ability to make important decisions, such as evaluating the pros and cons of energy production sources or voting on decisions about nuclear waste disposal.

This AP® Physics 1 course begins with **kinematics,** the study of motion without considering its causes. Motion is everywhere: from the vibration of atoms to the planetary revolutions around the Sun. Understanding motion is key to understanding other concepts in physics. You will then study **dynamics,** which considers the forces that affect the motion of moving objects and systems. Newton’s laws of motion are the foundation of dynamics. These laws provide an example of the breadth and simplicity of the principles under which nature functions. One of the most remarkable simplifications in physics is that only four distinct forces account for all known phenomena. Your journey will continue as you learn about energy. Energy plays an essential role both in everyday events and in scientific phenomena. You can likely name many forms of energy, from that provided by our foods, to the energy we use to run our cars, to the sunlight that warms us on the beach. The next stop is learning about oscillatory motion and waves. All oscillations involve force and energy: you push a child in a swing to get the motion started and you put energy into a guitar string when you pluck it. Some oscillations create waves. For example, a guitar creates sound waves. You will conclude this first physics course with the study of static electricity and electric currents. Many of the characteristics of static electricity can be explored by rubbing things together. Rubbing creates the spark you get from walking across a wool carpet, for example. Similarly, lightning results from air movements under certain weather conditions.

In the AP® Physics 2 course, you will continue your journey by studying **fluid dynamics,** which explains why rising smoke curls and twists and how the body regulates blood flow. The next stop is **thermodynamics,** the study of heat transfer—energy in transit—that can be used to do work. Basic physical laws govern how heat transfers and its efficiency. Then you will learn more about electric phenomena as you delve into **electromagnetism.** An electric current produces a magnetic field; similarly, a magnetic field produces a current. This phenomenon, known as **magnetic induction,** is essential to our technological society. The generators in cars and nuclear plants use magnetism to generate a current. Other devices that use magnetism to induce currents include pickup coils in electric guitars, transformers of every size, certain microphones, airport security gates, and damping mechanisms on sensitive chemical balances. From electromagnetism you will continue your journey to **optics,** the study of light. You already know that visible light is the type of electromagnetic waves to which our eyes respond. Through vision, light can evoke deep emotions, such as when we view a magnificent sunset or glimpse a rainbow breaking through the clouds. Optics is concerned with the generation and propagation of light. The **quantum mechanics, atomic physics,** and **nuclear physics** are at the end of your journey. These areas of physics have been developed at the end of the 19th and early 20th centuries and deal with submicroscopic objects. Because these objects are smaller than we can observe directly with our senses and generally must be observed with the aid of instruments, parts of these physics areas may seem foreign and bizarre to you at first. However, we have experimentally confirmed most of the ideas in these areas of physics.

AP® Physics is a challenging course. After all, you are taking physics at the introductory college level. You will discover that some concepts are more difficult to understand than others; most students, for example, struggle to understand rotational motion and angular momentum or particle-wave duality. The AP® curriculum promotes depth of understanding over breadth of content, and to make your exploration of topics more manageable, concepts are organized around seven major themes called the **Big Ideas** that apply to all levels of physical systems and interactions between them (see web diagram below). Each Big Idea identifies **enduring understandings** (EU), **essential knowledge** (EK), and **illustrative examples** that support key concepts and content. Simple descriptions define the focus of each Big Idea.

- Big Idea 1: Objects and systems have properties.
- Big Idea 2: Fields explain interactions.
- Big Idea 3: The interactions are described by forces.
- Big Idea 4: Interactions result in changes.
- Big Idea 5: Changes are constrained by conservation laws.
- Big Idea 6: Waves can transfer energy and momentum.
- Big Idea 7: The mathematics of probability can to describe the behavior of complex and quantum mechanical systems.

Doing college work is not easy, but completion of AP® classes is a reliable predictor of college success and prepares you for subsequent courses. The more you engage in the subject, the easier your journey through the curriculum will be. Bring your enthusiasm to class every day along with your notebook, pencil, and calculator. Prepare for class the day before, and review concepts daily. Form a peer study group and ask your teacher for extra help if necessary. The AP® lab program focuses on more open-ended, student-directed, and inquiry-based lab investigations designed to make you think, ask questions, and analyze data like scientists. You will develop critical thinking and reasoning skills and apply different means of communicating information. By the time you sit for the AP® exam in May, you will be fluent in the language of physics; because you have been doing real science, you will be ready to show what you have learned. Along the way, you will find the study of the world around us to be one of the most relevant and enjoyable experiences of your high school career.

Irina Lyublinskaya, PhD
Professor of Science Education

To the AP® Physics Teacher

The AP® curriculum was designed to allow instructors flexibility in their approach to teaching the physics courses. *College Physics for AP® Courses* helps you orient students as they delve deeper into the world of physics. Each chapter includes a Connection for AP® Courses introduction that describes the AP® Physics Big Ideas, enduring understandings, and essential knowledge addressed in that chapter.

Each section starts with specific AP® learning objectives and includes essential concepts, illustrative examples, and science practices, along with suggestions for applying the learning objectives through take-home experiments, virtual lab investigations, and activities and questions for preparation and review. At the end of each section, students will find the Test Prep for AP® courses with multiple-choice and open-response questions addressing AP® learning objectives to help them prepare for the AP® exam.

College Physics for AP® Courses has been written to engage students in their exploration of physics and help them relate what they learn in the classroom to their lives outside of it. Physics underlies much of what is happening today in other sciences and in technology. Thus, the book content includes interesting facts and ideas that go beyond the scope of the AP® course. The AP® Connection in each chapter directs students to the material they should focus on for the AP® exam, and what content—although interesting—is not part of the AP® curriculum. Physics is a beautiful and fascinating science. It is in your hands to engage and inspire your students to dive into an amazing world of physics, so they can enjoy it beyond just preparation for the AP® exam.

Irina Lyublinskaya, PhD
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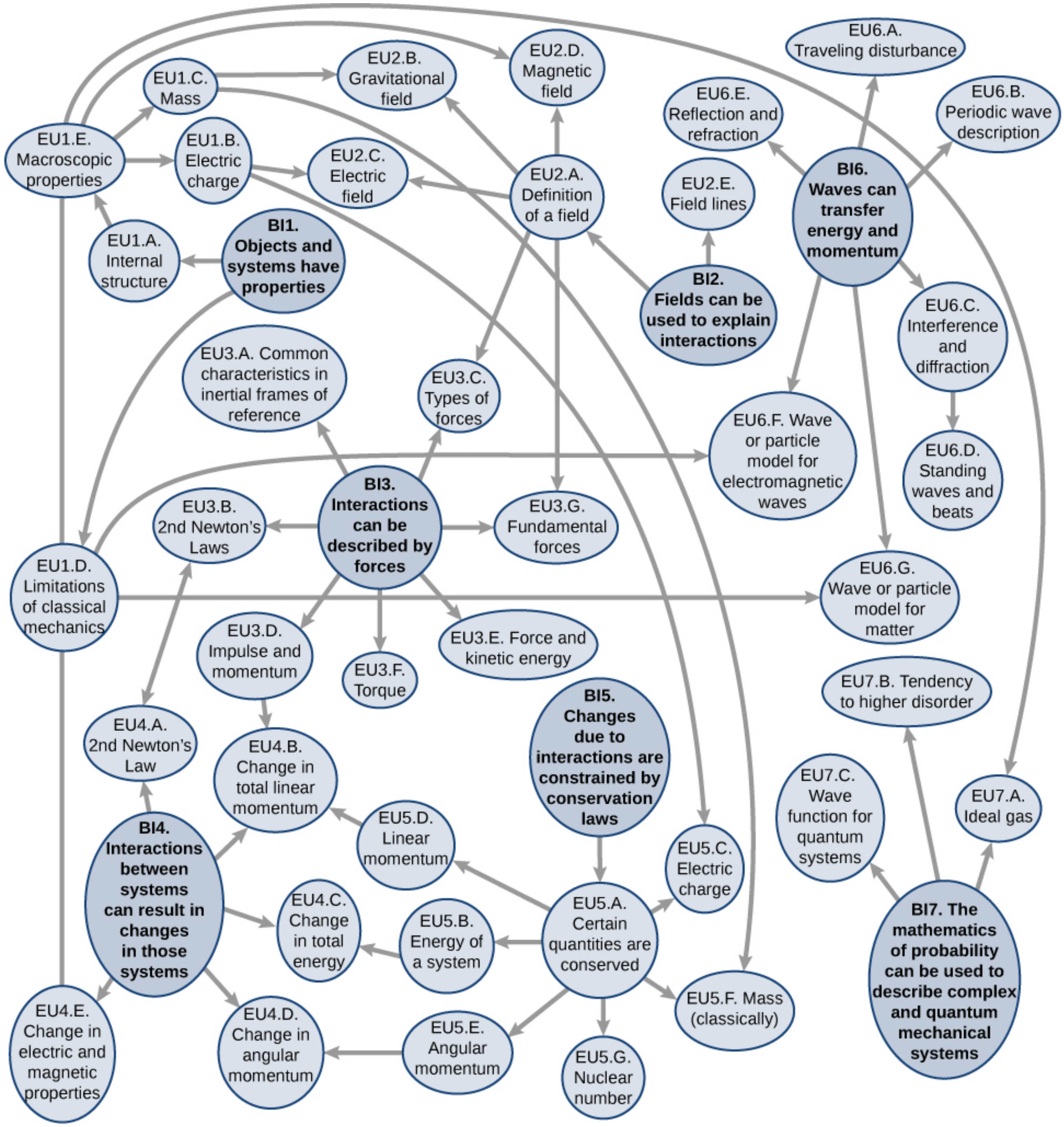

The concept map showing major links between Big Ideas and Enduring Understandings is provided below for visual reference.