NINTH EDITION

The Physical Universe

Includes Free Study Guide and CD-ROM

Konrad B. Krauskopf
Arthur Beiser

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PREFACE

THE TEXT

The aim of *The Physical Universe* is to present, as simply and clearly as possible, the essentials of physics, chemistry, earth science, and astronomy.

Because of the scope of these sciences and because we assume little preparation on the part of the reader, our choice of topics and how far to develop them had to be limited. The emphasis throughout is on the basic concepts of each discipline. We also wanted to show how science works, how scientists approach problems, and why science is a never-ending quest rather than a fixed set of facts. We hope to equip readers of the book to appreciate major developments in science in their later years and to understand questions of public policy related to science.

There are many possible ways to organize a book of this kind. We chose the one that provides the most logical progression of ideas, so that each new subject builds on the ones that came before.

Our first concern in *The Physical Universe* is the scientific method, using as illustration the steps that led to today's picture of the universe and the earth's place in it. Next we consider motion and the influences that affect moving bodies. Gravity, energy, and momentum are examined and the theory of relativity is introduced. Matter in its three states next draws our attention, and we pursue this theme from the kinetic-molecular model to the laws of thermodynamics and the significance of entropy. A grounding in electricity and magnetism follows, and then an exploration of wave phenomena that includes the electromagnetic theory of light. We go on from there to the atomic nucleus and elementary particles, followed by a discussion of the quantum theories of light and of matter that lead to the modern view of atomic structure.

The transition from physics to chemistry is made via the periodic table. A look at chemical bonds and how they act to hold together molecules, solids, and liquids is followed by a survey of chemical reactions, organic chemistry, and the chemistry of life.

Our concern now shifts to the planet on which we live, and we begin by inquiring into the oceans of air and water that cover it. From there we proceed to the materials of the earth, to its ever-evolving crust, and to its no-longer-mysterious interior. After a brief narrative of the earth's geological history we go on to what we know about our nearest neighbors in space—planets and satellites, asteroids, meteoroids, and comets.

Now the sun, the monarch of the solar system and the provider of nearly all our energy, claims our notice. We go on to broaden our astronomical sights to include the other stars, both individually and as members of the immense assemblies called galaxies. The evolution of the universe starting from the big bang is the last major subject, and we end with the origin of the earth and the likelihood that other inhabited planets exist in the universe and how we might communicate with them.

Because physical scientists rely on experimental data as both the source and the test of their findings, we think it important to include a few quantitative discussions. However, they are kept simple and supplement rather than dominate our arguments.

PEDAGOGICAL FEATURES

A variety of aids are provided in *The Physical Universe* to help the reader master the text.

Important Terms and Ideas. The meanings of important terms are given at the end of each chapter; this also serves as a chapter summary. A list of the formulas needed to solve problems based on the chapter material is also given where appropriate.

Multiple-Choice Exercises. An average chapter has 36 multiple-choice exercises (with answers) that act as a quick, painless check on understanding. Correct answers provide reinforcement and encouragement; incorrect ones identify areas of weakness.

Questions. Some of the questions are meant to find out how well the reader has understood the chapter material. Others ask the reader to apply what he or she has learned to new situations. Answers to the odd-numbered questions are given at the back of the book.

Problems. The physics and chemistry chapters include problems that range from quite easy to moderately challenging. Although not essential, being able to work out such problems signifies a real grasp of these subjects. Outline solutions (not just answers) for the odd-numbered problems are given at the back of the book.

THIS EDITION

Experience has shown that the existing organization of *The Physical Universe* works well in the classroom, so no changes were made in this aspect of the book. The emphasis in the revision was in the following areas:

(1) The contents were brought up to date.

(2) The coverage was enriched in various ways, principally by adding several dozen more sidebars (brief accounts of topics ancillary to the main text).

(3) Many of the end-of-chapter questions and problems were replaced with new ones and others added. The total number of exercises is now 1608.

(4) We have added a Web Site to the text package. This new component gives the text an interactive dimension and provide the student with additional ways to understand physical science.

Two new features introduced in the previous edition—biographical sketches of important contributors to the physical sciences and essays by distinguished young scientists—were much appreciated by users of that edition and have been kept for this one. The essays, by Timothy C. Miller (a physicist), Cynthia M. Friend (a chemist), Andrea Donellan (a geologist), and Wendy Freedman (an astronomer), give an idea of what a typical day at work involves for each of them and nicely conveys the excitement of being at the frontier of knowledge.

The Physical Universe **package teaches you how science works, how scientists approach problems, and why science constantly evolves in its search for understanding.**

TAKE A CONCEPTUAL APPROACH TO LEARNING

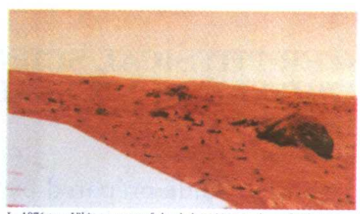
Krauskopf/Beiser takes a conceptual approach, with less mathematics than most physical science texts. *The Physical Universe* emphasizes knowledge of the scientific method and how scientists think. Though its discussion of many familiar and current topics, *The Physical Universe* helps you make the connection between science and the world around you.

LEARN WITH OUTSTANDING FEATURES

Updated Coverage. New material has been added to the text about energy sources, fuel cells, global warming, comets and meteors, the possibility of life elsewhere in the solar system, and much more.

558 16-558 CHAPTER 16 • The Solar System

PATHFINDER In July, 1997 the Pathfinder spacecraft landed on Mars and released the Sojourner rover to explore the rock-strewn Martian landscape nearby. The six-wheeled Sojourner was 60 cm long and 30 cm high and its cameras, instruments, radio transmitter, and electric motors were powered mainly by solar cells; its speed was about 1 cm/s (all of 0.02 mi/h). The landing place was in a plain that had been swept by a great flood over a billion years ago that washed down rocks from the adjacent highlands. The compositions of several of these rocks were studied by the instruments on Sojourner and the data were radioed to the lander for retransmission to the earth. A 10-year program of missions to Mars is planned to follow Pathfinder's voyage, including one in 2005 that is hoped to bring rock and soil samples back to the earth. Another mission will land on the edge of the south polar ice cap to investigate what seem to be layers of dust and ice desposited as the Martian climate alternated between cold and warm spells. Martian weather and the composition of its thin atmosphere will also be studied.



In 1976 two Viking spacecraft landed on Mars and sent back data and photographs such as this one. Martian rocks are porous and jagged, like basaltic lavas of the earth and moon, and the soil resembles weathered lava. Iron oxides are responsible for the red color. No trace of life was found.

Since conditions there long ago may have been comparable to those on the earth, life of some kind could have come into being on Mars. Then the carbon dioxide of the atmosphere gradually became incorporated in Martian rocks, as happens on the earth today. But Mars lacks the tectonic and volcanic processes that recycle the earth's carbon dioxide, so this gas, vital for the greenhouse effect, all but disappeared.

Where did the water go? Nobody knows, but much of it may remain permanently frozen below the Martian surface. These changes were very gradual, and it is not entirely absurd to speculate that living things there could have adapted to the progressively harsher environment and have survived in some form to the present.

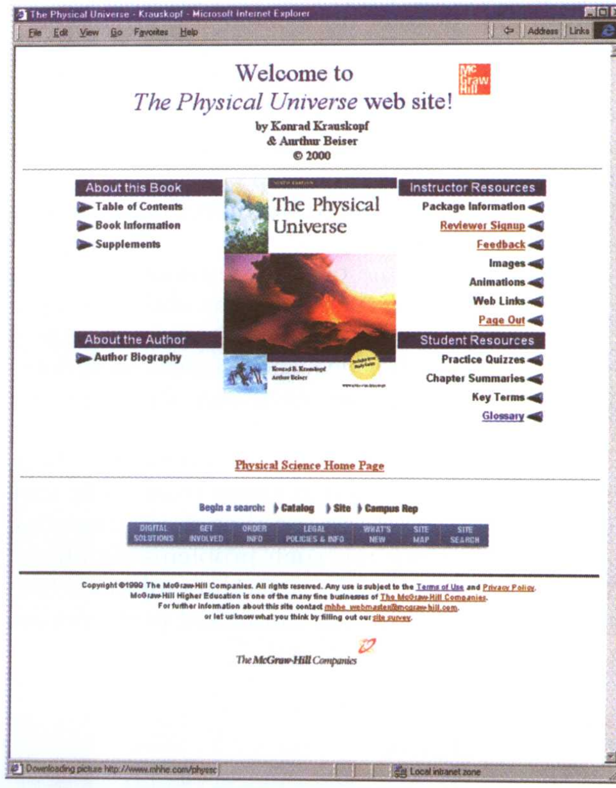
The absence of any sign of life in photographs taken from thousands of km away from the Martian surface means nothing. At such distances terrestrial life would probably not be apparent to a visitor from elsewhere (and a closer look might well suggest that the car is the most conspicuous type of life on earth).

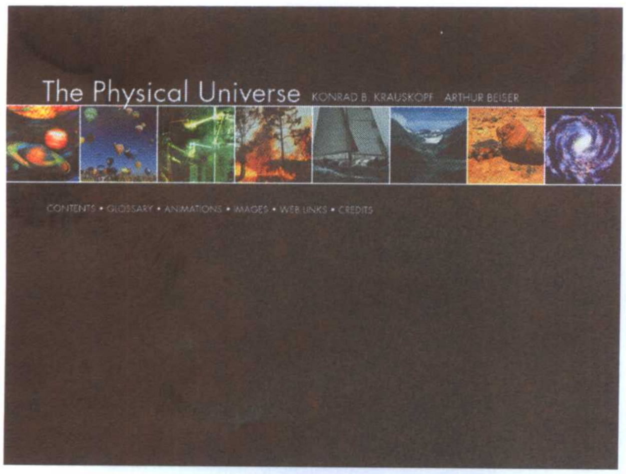
In 1976 two American Viking spacecraft landed on Mars. Among their various tasks were several sensitive experiments able to detect life in Martian soil. No evidence for present life or chemical traces left by past life was found. Even worse for the hypothesis of life on Mars, the

Math Refresher. Although the mathematical level of the book has been kept low, a little algebra is needed and is reviewed here. Powers-of-ten notation for small and large numbers is carefully explained. This section is self-contained and can provide all the math background needed.

LEARN VIA MULTIMEDIA

The *Physical Universe* Web site at www.mhhe.com/krauskopf. The Web site features images, chapter summaries, an existing list of Web links, quizzes, a glossary, and more.





MASTER PHYSICAL SCIENCE WITH *THE PHYSICAL UNIVERSE* STUDY GUIDE

The Study Guide prepared by Steven D. Carey of the University of Mobile, gives you the tools you need to review the material in the text and prepare for tests. Chapter Goals, Summaries and Outlines provide concise synopsis of the information presented in each chapter, and let you know which facts and ideas to concentrate on. Use the Study Guide's multiple choice, true and false, fill in the blank, and matching exercises to be sure you've mastered key terms and concepts. Many chapters also include a Solved Problems Section that guides you through several problems from that chapter, clarifying any questions you may have about problem-solving strategies.

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Konrad B. Krauskopf
Arthur Beiser

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The Planets

1 The Scientific Method

All of us belong to two worlds, the world of people and the world of nature. As members of the world of people, we take an interest in human events of the past and present and find such matters as politics and economics worth knowing about. As members of the world of nature, we also owe ourselves some knowledge of the sciences that seek to understand this world. It is not idle curiosity to ask why the sun shines, why the sky is blue, how old the earth is, why things fall down. These are serious questions, and to know their answers adds an important dimension to our personal lives.

We are made of atoms linked together into molecules, and we live on a planet circling a star—the sun—that is a member of one of the many galaxies of stars in the universe. It is the purpose of this book to survey what physics, chemistry, geology, and astronomy have to tell us about atoms and molecules, stars and galaxies, and everything in between. No single volume can cover all that is significant in this vast span, but the basic ideas of each science can be summarized along with the raw material of observation and reasoning that led to them.

Like any other voyage into the unknown, the exploration of nature is an adventure. This book records that adventure and contains many tales of wonder and discovery. The search for knowledge is far from over, with no end of exciting things still to be found. What some of these things might be and where they are being looked for are part of the story in the chapters to come.

HOW SCIENTISTS STUDY NATURE

Every scientist dreams of lighting up some dark corner of the natural world—or, almost as good, of finding a dark corner where none had been suspected. The most careful observations, the most elaborate calculations will not be fruitful unless the right questions are asked. Here is where creative imagination enters science, which is why most of the greatest scientific advances have been made by young, nimble minds.

Scientists study nature in a variety of ways. Some approaches are quite direct: a geologist takes a rock sample to a laboratory and, by inspection and analysis, finds out what it is made of and how and when it was probably formed. Other approaches are indirect: nobody has ever visited the center of the earth or ever will, but by combining a lot of thought with clues from different sources, a geologist can say with near certainty that the earth has a core of molten iron. No matter what the approaches to particular problems may be, however, the work scientists do always fits into a certain pattern of steps. This pattern, a general scheme for looking at the universe, has become known as the **scientific method.**

1-1 THE SCIENTIFIC METHOD

Four Steps We can think of the scientific method in terms of four steps: (1) formulating a problem, (2) observation and experiment, (3) interpreting the data, and (4) testing the interpretation by further observation and experiment. These steps are often carried out by different scientists, sometimes many years apart and not always in this order. Whatever way it is carried out, though, the scientific method

FINDING THE ROYAL ROAD Hermann von Helmholtz, a German physicist and biologist of a century ago, summed up his experience of scientific research in these words: "I would compare myself to a mountain climber who, not knowing the way, ascends slowly and toilsomely and is often compelled to retrace his steps because his progress is blocked; who, sometimes by reasoning and sometimes by accident, hits upon signs of a fresh path, which leads him a little farther; and who, finally, when he has reached his goal, discovers to his annoyance a royal road on which he might have ridden up if he had been clever enough to find the right starting point at the beginning."

is not a mechanical process but a human activity that needs creative thinking in all its steps. Looking at the natural world is at the heart of the scientific method, because the results of observation and experiment serve not only as the foundations on which scientists build their ideas but also as the means by which these ideas are checked (Fig. 1-1).

1. **Formulating a problem** may mean no more than choosing a certain field to work in, but more often a scientist has in mind some specific idea he or she wishes to investigate. In many cases formulating a problem and interpreting the data overlap. The scientist has a speculation, perhaps only a hunch, perhaps a fully developed concept, about some aspect of nature but cannot come to a definite conclusion without further study.
2. **Observation and experiment** are carried out with great care. Facts about nature are the building blocks of science and the ultimate test of its results. This insistence on accurate, objective data is what sets science apart from other modes of intellectual endeavor.
3. **Interpretation** may lead to a general rule to which the data seem to conform. Or it may be a more ambitious attempt to account for what has been found in terms of how nature works. In any case, the interpretation must be able to cover new data obtained under different circumstances. As put forward orginally, a scientific interpretation is usually called a **hypothesis**.
4. **Testing the interpretation** involves making new observations or performing new experiments to see whether the interpretation correctly predicts the results. If the results agree with the predictions, the scientist is clearly on the right track. The new data may well lead to refinements of the original idea, which in turn must be checked, and so on indefinitely.

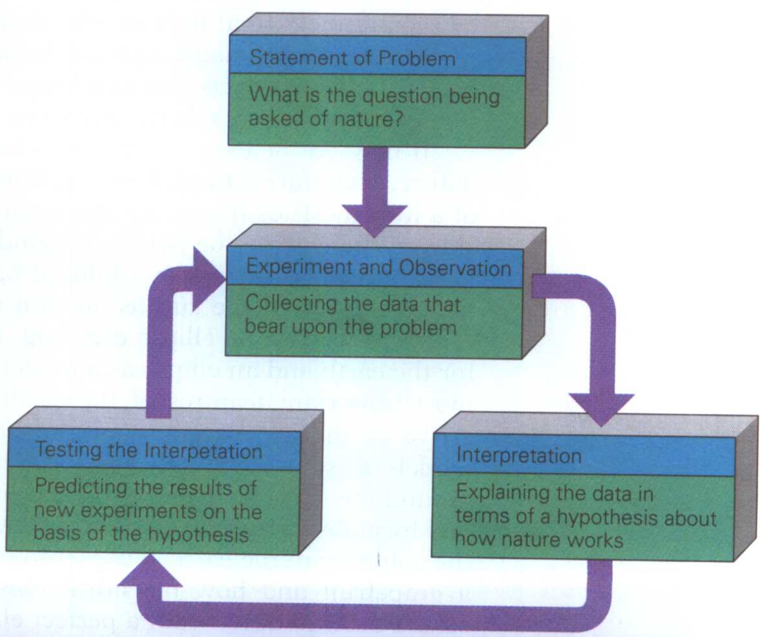

FIG. 1-1 The scientific method. No hypothesis is ever final because future data may show that it is incorrect or incomplete. Unless it turns out to be wrong, a hypothesis never leaves the loop of experiment, interpretation, testing. Of course, the more times the hypothesis goes around the loop successfully, the more likely it is to be a valid interpretation of nature. Experiment and hypothesis thus evolve together, with experiment having the final word. A hypothesis that has survived testing is called a law or theory.