

NINTH EDITION

The Physical Universe



Konrad B. Krauskopf
Arthur Beiser

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THE PHYSICAL UNIVERSE, NINTH EDITION

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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 Freed-

man (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.

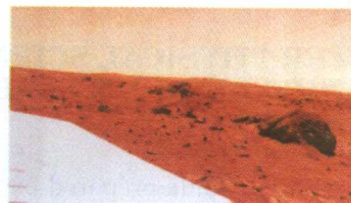
LEARN WITH OUTSTANDING FEATURES

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 deposited 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.

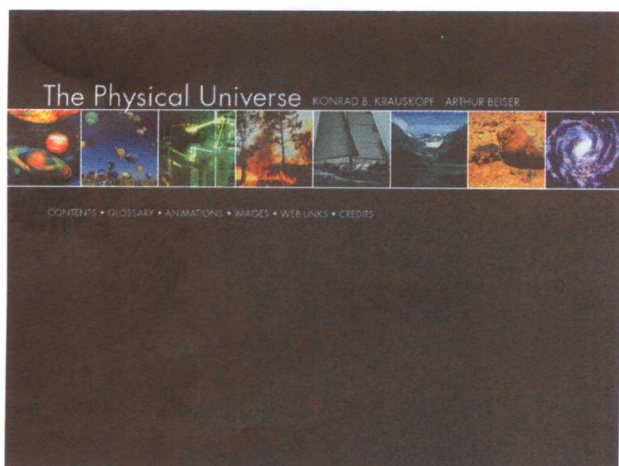
The absence of any sign of life in photographs taken from thousands of km away from the Martian surface means nothing. At such distances terrestrial life would probably not be apparent to a visitor from elsewhere (and a closer look might well suggest that the car is the most conspicuous type of life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

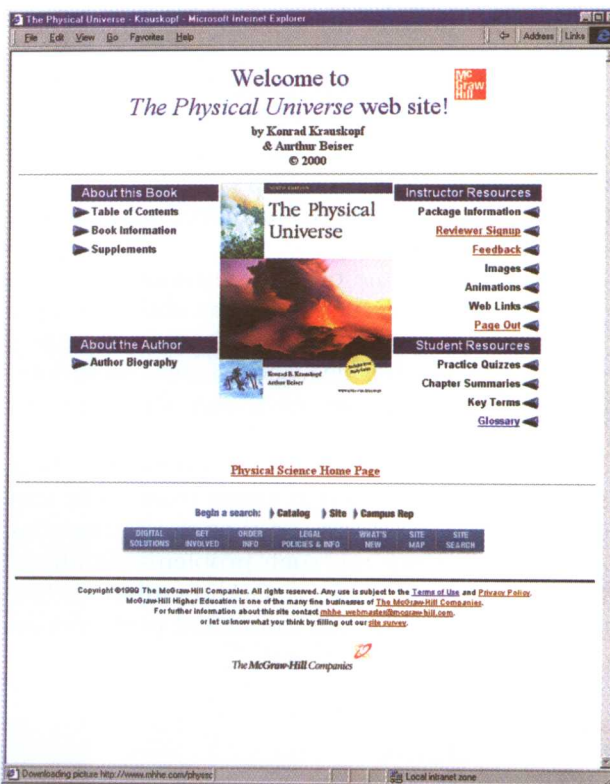
LEARN VIA MULTIMEDIA

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

BRIEF CONTENTS

	Preface	xii
CHAPTER 1	The Scientific Method	1
CHAPTER 2	Motion	27
CHAPTER 3	Energy	63
CHAPTER 4	Matter and Energy	95
CHAPTER 5	Electricity and Magnetism	133
CHAPTER 6	Waves	173
CHAPTER 7	The Nucleus	213
CHAPTER 8	The Atom	247
CHAPTER 9	The Periodic Law	277
CHAPTER 10	Crystals, Ions, and Solutions	311
CHAPTER 11	Chemical Reactions	341
CHAPTER 12	Organic Chemistry	373
CHAPTER 13	Atmosphere and Hydrosphere	411
CHAPTER 14	The Rock Cycle	451
CHAPTER 15	The Evolving Earth	495
CHAPTER 16	The Solar System	543
CHAPTER 17	The Stars	581
CHAPTER 18	The Universe	611
	Math Refresher	A-1
	The Elements	A-13
	Answers to Odd-Numbered Questions and Problems	A-14
	Glossary	A-28
	Credits	A-40
	Index	I-1

CONTENTS

Preface xii

CHAPTER 1

THE SCIENTIFIC METHOD 1

HOW SCIENTISTS STUDY NATURE 2

- 1-1 The Scientific Method 2
- 1-2 Why Science Is Successful 5

THE SOLAR SYSTEM 5

- 1-3 A Survey of the Sky 6
- 1-4 The Ptolemaic System 8
- 1-5 The Copernican System 9
- 1-6 Kepler's Laws 11
- 1-7 Why Copernicus Was Right 15

UNIVERSAL GRAVITATION 15

- 1-8 What Is Gravity? 16
- 1-9 Why the Earth Is Round 20
- 1-10 The Tides 21
- 1-11 The Discovery of Neptune 23

Important Terms and Ideas 23
Exercises 24

CHAPTER 2

MOTION 27

DESCRIBING MOTION 28

- 2-1 Speed 28
- 2-2 Units 30
- 2-3 Vectors 32
- 2-4 Acceleration 34

ACCELERATION OF GRAVITY 36

- 2-5 Free Fall 39
- 2-6 Air Resistance 39

FORCE AND MOTION 40

- 2-7 First Law of Motion 40
- 2-8 Mass 41
- 2-9 Second Law of Motion 43
- 2-10 Mass and Weight 45
- 2-11 Third Law of Motion 46

GRAVITATION 48

- 2-12 Circular Motion 48
- 2-13 Newton's Law of Gravity 50
- 2-14 Mass of the Earth 52
- 2-15 Artificial Satellites 53

Important Terms and Ideas 55
Important Formulas 56
Exercises 56

CHAPTER 3

ENERGY 63

WORK 64

- 3-1 The Meaning of Work 64
- 3-2 Power 65

ENERGY 66

- 3-3 Kinetic Energy 67
- 3-4 Potential Energy 68
- 3-5 Energy Transformations 70
- 3-6 Conservation of Energy 72
- 3-7 The Nature of Heat 73

MOMENTUM 74

- 3-8 Linear Momentum 74
- 3-9 Rockets 77
- 3-10 Angular Momentum 78

RELATIVITY 79

- 3-11 Special Relativity 80

- 3-12 Rest Energy 82
3-13 General Relativity 84

ENERGY AND CIVILIZATION 85

- 3-14 The Energy Problem 85
3-15 The Future 88

Important Ideas and Terms 89

Important Formulas 89

Exercises 89

CHAPTER 4

MATTER AND ENERGY 95

TEMPERATURE AND HEAT 96

- 4-1 Temperature 96
4-2 Heat 99
4-3 Metabolic Energy 100

FLUIDS 102

- 4-4 Density 102
4-5 Pressure 103
4-6 Buoyancy 106
4-7 The Gas Laws 107

KINETIC THEORY OF MATTER 111

- 4-8 Kinetic Theory of Gases 111
4-9 Molecular Motion and Temperature 112

CHANGES OF STATE 114

- 4-10 Liquids and Solids 114
4-11 Evaporation and Boiling 115
4-12 Melting 117

ENERGY TRANSFORMATIONS 119

- 4-13 Heat Engines 119
4-14 Thermodynamics 121
4-15 Fate of the Universe 123
4-16 Entropy 124

Important Terms and Ideas 125

Important Formulas 126

Exercises 126

CHAPTER 5

ELECTRICITY AND MAGNETISM 133

ELECTRIC CHARGE 134

- 5-1 Positive and Negative Charge 134
5-2 What Is Charge? 136

- 5-3 Coulomb's Law 138
5-4 Force on an Uncharged Object 139

ELECTRICITY AND MATTER 140

- 5-5 Matter in Bulk 140
5-6 Conductors and Insulators 140
5-7 Superconductivity 142

ELECTRIC CURRENT 143

- 5-8 The Ampere 143
5-9 Potential Difference 144
5-10 Ohm's Law 146
5-11 Electric Power 148

MAGNETISM 150

- 5-12 Magnets 150
5-13 Magnetic Field 151
5-14 Oersted's Experiment 152
5-15 Electromagnets 155

USING MAGNETISM 155

- 5-16 Magnetic Force on a Current 156
5-17 Electric Motors 158
5-18 Electromagnetic Induction 159
5-19 Transformers 162
5-20 Tape Recorders 164

Important Terms and Ideas 165

Important Formulas 165

Exercises 166

CHAPTER 6

WAVES 173

WAVE MOTION 174

- 6-1 Water Waves 174
6-2 Transverse and Longitudinal Waves 175
6-3 Sound 176
6-4 Describing Waves 178

WAVE BEHAVIOR 180

- 6-5 Refraction 180
6-6 Reflection 182
6-7 Interference 183
6-8 Diffraction 185
6-9 Doppler Effects 185
6-10 Musical Sounds 187

ELECTROMAGNETIC WAVES 190

- 6-11 Electromagnetic Waves 190

6-12 Types of EM Waves 192

LIGHT 194

6-13 Light "Rays" 195
 6-14 Reflection of Light 195
 6-15 Refraction of Light 196
 6-16 Lenses 198
 6-17 The Eye 200
 6-18 Color 202
 6-19 Interference of Light 206
 6-20 Diffraction of Light 207

Important Terms and Ideas 208

Important Formulas 209

Exercises 209

CHAPTER 7

THE NUCLEUS 213

ATOM AND NUCLEUS 214

7-1 Rutherford Model of the Atom 214
 7-2 Nuclear Structure 216

RADIOACTIVITY 218

7-3 Radioactive Decay 218
 7-4 Half-Life 221
 7-5 Radiation Hazards 222

NUCLEAR ENERGY 224

7-6 Units of Mass and Energy 224
 7-7 Binding Energy 224
 7-8 Binding Energy per Nucleon 226

FISSION AND FUSION 227

7-9 Nuclear Fission 228
 7-10 How a Reactor Works 229
 7-11 Plutonium 231
 7-12 A Nuclear World? 231
 7-13 Nuclear Fusion 233

ELEMENTARY PARTICLES 234

7-14 Antiparticles 235
 7-15 Fundamental Interactions 238
 7-16 Leptons and Hadrons 240

A Physicist at Work: Timothy C. Miller 240

Important Terms and Ideas 242

Exercises 243

CHAPTER 8

THE ATOM 247

QUANTUM THEORY OF LIGHT 248

8-1 Photoelectric Effect 248
 8-2 Photons 249
 8-3 What Is Light? 251
 8-4 X-Rays 252

MATTER WAVES 254

8-5 De Broglie Waves 254
 8-6 Waves of What? 256
 8-7 Uncertainty Principle 256

THE HYDROGEN ATOM 258

8-8 Atomic Spectra 258
 8-9 The Bohr Model 261
 8-10 Electron Waves and Orbits 263
 8-11 The Laser 264

QUANTUM THEORY OF THE ATOM 267

8-12 Quantum Mechanics 267
 8-13 Quantum Numbers 269
 8-14 Exclusion Principle 270

Important Terms and Ideas 271

Important Formulas 271

Exercises 271

CHAPTER 9

THE PERIODIC LAW 277

ELEMENTS AND COMPOUNDS 278

9-1 Chemical Change 278
 9-2 Three Classes of Matter 279
 9-3 The Atomic Theory 282

THE PERIODIC LAW 284

9-4 Metals and Nonmetals 284
 9-5 Chemical Activity 286
 9-6 Families of Elements 286
 9-7 The Periodic Table 288
 9-8 Groups and Periods 291

ATOMIC STRUCTURE 293

9-9 Shells and Subshells 293
 9-10 Explaining the Periodic Table 294

CHEMICAL BONDS 297

- 9-11 Types of Bond 297
- 9-12 Covalent Bonding 298
- 9-13 Ionic Bonding 299
- 9-14 Ionic Compounds 300
- 9-15 Atom Groups 301
- 9-16 Naming Compounds 302
- 9-17 Chemical Equations 303

Important Terms and Ideas 305

Exercises 305

CHAPTER 10**CRYSTALS, IONS, AND SOLUTIONS 311****SOLIDS 312**

- 10-1 Ionic and Covalent Crystals 313
- 10-2 The Metallic Bond 315
- 10-3 Molecular Crystals 316

SOLUTIONS 319

- 10-4 Solubility 319
- 10-5 Polar and Nonpolar Liquids 322
- 10-6 Ions in Solution 324
- 10-7 Evidence for Dissociation 325
- 10-8 Water 327
- 10-9 Water Pollution 328

ACIDS AND BASES 331

- 10-10 Acids 331
- 10-11 Strong and Weak Acids 332
- 10-12 Bases 333
- 10-13 The pH Scale 334
- 10-14 Salts 335

Important Terms and Ideas 337

Exercises 337

CHAPTER 11**CHEMICAL REACTIONS 341****COMBUSTION 342**

- 11-1 Phlogiston 342
- 11-2 Oxygen 345

CHEMICAL ENERGY 346

- 11-3 Exothermic and Endothermic Reactions 347

- 11-4 Chemical Energy and Stability 348
- 11-5 Activation Energy 350

FUELS 351

- 11-6 Liquid Fuels 351
- 11-7 Gas Fuels 354
- 11-8 Solid Fuels 355

REACTION RATES 356

- 11-9 Temperature 357
- 11-10 Concentration and Surface Area 358
- 11-11 Catalysts 358

A Chemist at Work: Cynthia M. Friend 359

- 11-12 Chemical Equilibrium 360
- 11-13 Altering an Equilibrium 361

OXIDATION AND REDUCTION 361

- 11-14 Electrolysis 362
- 11-15 Electrochemical Cells 364

Important Terms and Ideas 367

Exercises 367

CHAPTER 12**ORGANIC CHEMISTRY 373****CARBON COMPOUNDS 374**

- 12-1 Carbon Bonds 374
- 12-2 Alkanes 375
- 12-3 Petroleum Products 376

STRUCTURES OF ORGANIC MOLECULES 379

- 12-4 Structural Formulas 379
- 12-5 Isomers 379
- 12-6 Unsaturated Hydrocarbons 380
- 12-7 Benzene 382

ORGANIC COMPOUNDS 383

- 12-8 Hydrocarbon Groups 384
- 12-9 Functional Groups 384
- 12-10 Polymers 388

CHEMISTRY OF LIFE 392

- 12-11 Carbohydrates 393
- 12-12 Photosynthesis 395
- 12-13 Lipids 396
- 12-14 Proteins 397
- 12-15 Soil Nitrogen 399
- 12-16 Nucleic Acids 400
- 12-17 Origin of Life 403

Important Terms and Ideas 405
Exercises 405

CHAPTER 13

ATMOSPHERE AND HYDROSPHERE 411

THE ATMOSPHERE 412

- 13-1 Regions of the Atmosphere 412
- 13-2 Atmospheric Moisture 415
- 13-3 Clouds 416

WEATHER 420

- 13-4 Atmospheric Energy 420
- 13-5 The Seasons 422
- 13-6 Winds 424
- 13-7 General Circulation of the Atmosphere 426
- 13-8 Middle-Latitude Weather Systems 428

CLIMATE 433

- 13-9 Tropical Climates 434
- 13-10 Middle-Latitude Climates 435
- 13-11 Climatic Change 435
- 13-12 Origins of Climatic Change 437

THE HYDROSPHERE 440

- 13-13 Ocean Basins 440
- 13-14 Ocean Currents 442

Important Terms and Ideas 444
Exercises 445

CHAPTER 14

THE ROCK CYCLE 451

ROCKS 452

- 14-1 Composition of the Crust 452
- 14-2 Minerals 453
- 14-3 Igneous Rocks 456
- 14-4 Sedimentary Rocks 458
- 14-5 Metamorphic Rocks 460

WITHIN THE EARTH 462

- 14-6 Earthquakes 462
A Geologist at Work: Andrea Donellan 464
- 14-7 Structure of the Earth 466
- 14-8 The Earth's Interior 470
- 14-9 Geomagnetism 471

EROSION 472

- 14-10 Weathering 473
- 14-11 Stream Erosion 475
- 14-12 Glaciers 477
- 14-13 Groundwater 478
- 14-14 Sedimentation 480

VULCANISM 483

- 14-15 Volcanoes 483
- 14-16 Intrusive Rocks 486
- 14-17 The Rock Cycle 488

Important Terms and Ideas 488
Exercises 489

CHAPTER 15

THE EVOLVING EARTH 495

TECTONIC MOVEMENT 496

- 15-1 Types of Deformation 496
- 15-2 Mountain Building 498
- 15-3 Continental Drift 500

PLATE TECTONICS 503

- 15-4 Lithosphere and Asthenosphere 503
- 15-5 The Ocean Floors 504
- 15-6 Ocean-Floor Spreading 507
- 15-7 Plate Tectonics 508

METHODS OF HISTORICAL GEOLOGY 514

- 15-8 Principle of Uniform Change 514
- 15-9 Rock Formations 516
- 15-10 Radiometric Dating 518
- 15-11 Fossils 520
- 15-12 Geochronology 522

EARTH HISTORY 524

- 15-13 Precambrian Time 525
- 15-14 The Paleozoic Era 526
- 15-15 Coal and Petroleum 527
- 15-16 The Mesozoic Era 529
- 15-17 The Cenozoic Era 532
- 15-18 The Ice Age 533
- 15-19 Population and the Future 535

Important Terms and Ideas 537
Exercises 537

CHAPTER 16**THE SOLAR SYSTEM 543****THE FAMILY OF THE SUN 544**

- 16-1 The Solar System 545
- 16-2 Comets 546
- 16-3 Meteors 549

THE INNER PLANETS 551

- 16-4 Mercury 551
- 16-5 Venus 552
- 16-6 Mars 555
- 16-7 Is There Life on Mars? 557
- 16-8 Asteroids 559

THE OUTER PLANETS 560

- 16-9 Jupiter 560
- 16-10 Saturn 563
- 16-11 Uranus, Neptune, Pluto 565

THE MOON 567

- 16-12 Phases 568
- 16-13 Eclipses 569
- 16-14 The Lunar Surface 571
- 16-15 Evolution of the Lunar Landscape 573
- 16-16 Origin of the Moon 575

Important Terms and Ideas 577
Exercises 577

CHAPTER 17**THE STARS 581****TOOLS OF ASTRONOMY 582**

- 17-1 The Telescope 582
- 17-2 The Spectrometer 584
- 17-3 Spectrum Analysis 585

THE SUN 586

- 17-4 Properties of the Sun 587
- 17-5 The Aurora 588
- 17-6 Sunspots 590
- 17-7 Solar Energy 591

THE STARS 594

- 17-8 Stellar Distances 594
- 17-9 Variable Stars 595

- 17-10 Stellar Motions 597
- 17-11 Stellar Properties 597

LIFE HISTORIES OF THE STARS 599

- 17-12 H-R Diagram 599
- 17-13 Stellar Evolution 601
- 17-14 Supernovas 603
- 17-15 Pulsars 604
- 17-16 Black Holes 605

Important Terms and Ideas 606
Exercises 606

CHAPTER 18**THE UNIVERSE 611****GALAXIES 612**

- 18-1 The Milky Way 612
- 18-2 Stellar Populations 614
- 18-3 Radio Astronomy 615
- 18-4 Spiral Galaxies 616
- 18-5 Cosmic Rays 618

THE EXPANDING UNIVERSE 619

- 18-6 Red Shifts 619
- 18-7 Quasars 622

EVOLUTION OF THE UNIVERSE 622

- 18-8 Dating the Universe 623
- 18-9 The Cyclic Universe 623
- An Astronomer at Work: Wendy Freedman 624*
- 18-10 The Primeval Fireball 625
- 18-11 Origin of the Earth 627

EXTRATERRESTRIAL LIFE 629

- 18-12 Other Planetary Systems 630
- 18-13 Interstellar Travel 631
- 18-14 Interstellar Communication 631

Important Terms and Ideas 633
Exercises 633

MATH REFRESHER A-1**THE ELEMENTS A-13****ANSWERS TO ODD-NUMBERED****QUESTIONS AND PROBLEMS A-14****GLOSSARY A-28****PHOTO CREDITS A-40****INDEX I-1**



The Planets

1

The Scientific Method

HOW SCIENTISTS STUDY NATURE

- 1.1 The Scientific Method
- 1.2 Why Science Is Successful

THE SOLAR SYSTEM

- 1.3 A Survey of the Sky
- 1.4 The Ptolemaic System
- 1.5 The Copernican System
- 1.6 Kepler's Laws
- 1.7 Why Copernicus Was Right

UNIVERSAL GRAVITATION

- 1.8 What Is Gravity?
- 1.9 Why the Earth Is Round
- 1.10 The Tides
- 1.11 The Discovery of Neptune

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 originally, 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.

