

CONTENTS

Preface xii

1 What Is Science? 1



- 1.1 Objects and Properties 2
- 1.2 Quantifying Properties 3
- 1.3 Measurement Systems 4
- 1.4 Standard Units for the Metric System 5
 - Length 5
 - Mass 5
 - Time 6
- 1.5 Metric Prefixes 6
- 1.6 Understandings from Measurements 7
 - Data 7
 - Ratios and Generalizations 7
 - The Density Ratio 8
 - Symbols and Equations 10
 - How to Solve Problems 11
- 1.7 The Nature of Science 13
 - The Scientific Method 14
 - Explanations and Investigations 14
- Science and Society: Basic and Applied Research 15**
 - Laws and Principles 17
 - Models and Theories 17
- Summary* 19
- People Behind the Science: Florence Bascom 20**
 - Key Terms* 21
 - Applying the Concepts* 21
 - Questions for Thought* 23
 - For Further Analysis* 24
 - Invitation to Inquiry* 24
 - Parallel Exercises* 24

PHYSICS

2 Motion 25



- 2.1 Describing Motion 26
- 2.2 Measuring Motion 27
 - Speed 27
 - Velocity 29
 - Acceleration 29
- Science and Society: Transportation and the Environment 31**
 - Forces 32
- 2.3 Horizontal Motion on Land 34
- 2.4 Falling Objects 35
- A Closer Look: A Bicycle Racer's Edge 37**
- 2.5 Compound Motion 38
 - Vertical Projectiles 38
 - Horizontal Projectiles 38
- A Closer Look: Free Fall 39**
- 2.6 Three Laws of Motion 40
 - Newton's First Law of Motion 41
 - Newton's Second Law of Motion 41
 - Weight and Mass 43
 - Newton's Third Law of Motion 44
- 2.7 Momentum 46
 - Conservation of Momentum 46
 - Impulse 48
- 2.8 Forces and Circular Motion 48
- 2.9 Newton's Law of Gravitation 49
 - Earth Satellites 52
- A Closer Look: Gravity Problems 53**
 - Weightlessness 53
- People Behind the Science: Isaac Newton 54**
 - Summary* 55

- Key Terms* 56
- Applying the Concepts* 56
- Questions for Thought* 59
- For Further Analysis* 59
- Invitation to Inquiry* 59
- Parallel Exercises* 59

3 Energy 61



- 3.1 Work 62
 - Units of Work 62
- A Closer Look: Simple Machines 64**
 - Power 64
- 3.2 Motion, Position, and Energy 67
 - Potential Energy 67
 - Kinetic Energy 68
- 3.3 Energy Flow 69
 - Work and Energy 69
 - Energy Forms 70
 - Energy Conversion 71
 - Energy Conservation 74
 - Energy Transfer 74
- 3.4 Energy Sources Today 74
- Science and Society: Grow Your Own Fuel? 75**
 - Petroleum 75
 - Coal 75
- People Behind the Science: James Prescott Joule 76**
 - Moving Water 76
 - Nuclear 77
 - Conserving Energy 77
- 3.5 Energy Sources Tomorrow 78
 - Solar Technologies 78
 - Geothermal Energy 79
 - Hydrogen 80
- Summary* 80
- Key Terms* 81
- Applying the Concepts* 81
- Questions for Thought* 83
- For Further Analysis* 83
- Invitation to Inquiry* 83
- Parallel Exercises* 83

4 Heat and Temperature 85



- 4.1 The Kinetic Molecular Theory 86
 - Molecules 86
 - Molecules Interact 87
 - Phases of Matter 87
 - Molecules Move 88
- 4.2 Temperature 89
 - Thermometers 89
 - Temperature Scales 90
- A Closer Look: Goose Bumps and Shivering 92**
- 4.3 Heat 92
 - Heat as Energy Transfer 93
 - Measures of Heat 94
 - Specific Heat 94
 - Heat Flow 96
- Science and Society: Require Insulation? 97**
- 4.4 Energy, Heat, and Molecular Theory 98
 - Phase Change 99
- A Closer Look: Passive Solar Design 101**
 - Evaporation and Condensation 102
- 4.5 Thermodynamics 104
 - The First Law of Thermodynamics 104
 - The Second Law of Thermodynamics 105
 - The Second Law and Natural Processes 106
- People Behind the Science: Count Rumford (Benjamin Thompson) 107**
 - Summary 108
 - Key Terms 109
 - Applying the Concepts 109
 - Questions for Thought 111
 - For Further Analysis 112
 - Invitation to Inquiry 112
 - Parallel Exercises 112

5 Wave Motions and Sound 115



- 5.1 Forces and Elastic Materials 116
 - Forces and Vibrations 116
 - Describing Vibrations 117
- 5.2 Waves 118
 - Kinds of Mechanical Waves 119
 - Waves in Air 119
- 5.3 Describing Waves 120
- 5.4 Sound Waves 122
 - Sound Waves in Air and Hearing 122
 - Medium Required 122
- A Closer Look: Hearing Problems 123**
 - Velocity of Sound in Air 123
 - Refraction and Reflection 124
 - Interference 126
- 5.5 Energy of Waves 127
 - How Loud Is That Sound? 127
 - Resonance 128
- 5.6 Sources of Sounds 129
 - Vibrating Strings 129
- Science and Society: Laser Bug 131**
 - Sounds from Moving Sources 131
- People Behind the Science: Johann Christian Doppler 132**
- A Closer Look: Doppler Radar 133**
 - Summary 133
 - Key Terms 134
 - Applying the Concepts 134
 - Questions for Thought 137
 - For Further Analysis 137
 - Invitation to Inquiry 137
 - Parallel Exercises 137

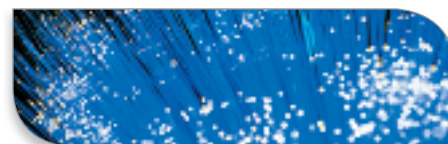
6 Electricity 139



- 6.1 Concepts of Electricity 140
 - Electron Theory of Charge 140
 - Measuring Electrical Charges 143

- Electrostatic Forces 144
- Force Fields 144
- Electric Potential 145
- 6.2 Electric Current 146
 - The Electric Circuit 146
 - The Nature of Current 148
 - Electrical Resistance 150
 - Electrical Power and Electrical Work 151
- People Behind the Science: Benjamin Franklin 153**
- 6.3 Magnetism 154
 - Magnetic Poles 154
 - Magnetic Fields 154
 - The Source of Magnetic Fields 156
- 6.4 Electric Currents and Magnetism 158
 - Current Loops 158
 - Applications of Electromagnets 158
- 6.5 Electromagnetic Induction 161
- A Closer Look: Current War 162**
 - Generators 162
 - Transformers 162
- 6.6 Circuit Connections 165
 - Voltage Sources in Circuits 165
- Science and Society: Blackout Reveals Pollution 166**
 - Resistances in Circuits 166
- A Closer Look: Solar Cells 167**
 - Household Circuits 168
- Summary 170
- Key Terms 172
- Applying the Concepts 172
- Questions for Thought 175
- For Further Analysis 175
- Invitation to Inquiry 175
- Parallel Exercises 175

7 Light 177



- 7.1 Sources of Light 178
- 7.2 Properties of Light 180
 - Light Interacts with Matter 180
 - Reflection 182
 - Refraction 183
 - Dispersion and Color 185
- A Closer Look: Optics 186**
- 7.3 Evidence for Waves 189
 - Interference 189

- A Closer Look: The Rainbow** 190
 - Polarization 190
- A Closer Look: Lasers** 191
- A Closer Look: Why Is the Sky Blue?** 192
- 7.4 Evidence for Particles 192
 - Photoelectric Effect 193
 - Quantization of Energy 193
- 7.5 The Present Theory 194
- A Closer Look: The Compact Disc (CD)** 195
- Relativity 196
 - Special Relativity 196
- People Behind the Science: James Clerk Maxwell** 197
 - General Theory 197
 - Relativity Theory Applied 198
- Summary* 198
- Key Terms* 199
- Applying the Concepts* 199
- Questions for Thought* 201
- For Further Analysis* 202
- Invitation to Inquiry* 202
- Parallel Exercises* 202

CHEMISTRY

8 Atoms and Periodic Properties 203



- 8.1 Atomic Structure
 - Discovered 204
 - Discovery of the Electron 204
 - The Nucleus 206
- 8.2 The Bohr Model 208
 - The Quantum Concept 208
 - Atomic Spectra 208
 - Bohr's Theory 209
- 8.3 Quantum Mechanics 212
 - Matter Waves 212
 - Wave Mechanics 213
 - The Quantum Mechanics Model 213
- Science and Society: Atomic Research** 214
- 8.4 Electron Configuration 215
- 8.5 The Periodic Table 216
- 8.6 Metals, Nonmetals, and Semiconductors 218
- A Closer Look: The Rare Earths** 219
- People Behind the Science: Dmitri Ivanovich Mendeleev** 220

- Summary* 221
- Key Terms* 222
- Applying the Concepts* 222
- Questions for Thought* 225
- For Further Analysis* 225
- Invitation to Inquiry* 225
- Parallel Exercises* 226

9 Chemical Bonds 229



- 9.1 Compounds and Chemical Change 230
- 9.2 Valence Electrons and Ions 232
- 9.3 Chemical Bonds 233
 - Ionic Bonds 234
 - Covalent Bonds 236
- 9.4 Bond Polarity 238
- 9.5 Composition of Compounds 240
 - Ionic Compound Names 241
 - Ionic Compound Formulas 241
 - Covalent Compound Names 242
- Science and Society: Microwave Ovens and Molecular Bonds** 243
 - Covalent Compound Formulas 244

- People Behind the Science: Linus Carl Pauling** 245
 - Summary* 245
 - Key Terms* 246
 - Applying the Concepts* 246
 - Questions for Thought* 249
 - For Further Analysis* 249
 - Invitation to Inquiry* 249
 - Parallel Exercises* 250

10 Chemical Reactions 251



- 10.1 Chemical Formulas 252
 - Molecular and Formula Weights 253
 - Percent Composition of Compounds 253
- 10.2 Chemical Equations 255
 - Balancing Equations 255
 - Generalizing Equations 259

- 10.3 Types of Chemical Reactions 260
 - Combination Reactions 260
 - Decomposition Reactions 261
 - Replacement Reactions 261
 - Ion Exchange Reactions 262
- 10.4 Information from Chemical Equations 263
 - Units of Measurement Used with Equations 265
 - Quantitative Uses of Equations 266

Science and Society: The Catalytic Converter 267

People Behind the Science: Emma Perry Carr 268

- Summary* 268
- Key Terms* 269
- Applying the Concepts* 269
- Questions for Thought* 271
- For Further Analysis* 272
- Invitation to Inquiry* 272
- Parallel Exercises* 272

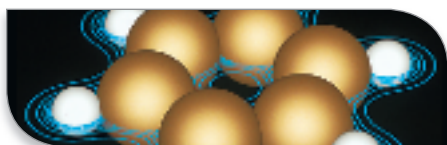
11 Water and Solutions 275



- 11.1 Household Water 276
- 11.2 Properties of Water 276
 - Structure of Water Molecules 277
- Science and Society: Who Has the Right?** 278
 - The Dissolving Process 279
 - Concentration of Solutions 280
- A Closer Look: Decompression Sickness** 283
 - Solubility 283
- 11.3 Properties of Water Solutions 284
 - Electrolytes 284
 - Boiling Point 285
 - Freezing Point 286
- 11.4 Acids, Bases, and Salts 286
 - Properties of Acids and Bases 286
 - Explaining Acid-Base Properties 288
 - Strong and Weak Acids and Bases 288
 - The pH Scale 289

- Properties of Salts 290
- Hard and Soft Water 290
- A Closer Look: Acid Rain 292**
- People Behind the Science:**
- Johannes Nicolaus Brönsted 293**
- Summary 293*
- Key Terms 294*
- Applying the Concepts 294*
- Questions for Thought 296*
- For Further Analysis 296*
- Invitation to Inquiry 297*
- Parallel Exercises 297*

12 Organic Chemistry 299



- 12.1 Organic Compounds 300
- 12.2 Hydrocarbons 300
 - Alkenes and Alkynes 302
 - Cycloalkanes and Aromatic Hydrocarbons 304
- 12.3 Petroleum 305
- 12.4 Hydrocarbon Derivatives 307
 - Alcohols 308
 - Ethers, Aldehydes, and Ketones 309
 - Organic Acids and Esters 309
- Science and Society: Aspirin, a Common Organic Compound 310**
- 12.5 Organic Compounds of Life 311
 - Proteins 311
 - Carbohydrates 312
 - Fats and Oils 313
 - Synthetic Polymers 314
- A Closer Look: How to Sort Plastic Bottles for Recycling 316**
- People Behind the Science: Alfred Bernhard Nobel 317**
- Summary 318*
- Key Terms 318*
- Applying the Concepts 319*
- Questions for Thought 321*
- For Further Analysis 321*
- Invitation to Inquiry 322*
- Parallel Exercises 322*

13 Nuclear Reactions 323



- 13.1 Natural Radioactivity 324
 - Nuclear Equations 325
 - The Nature of the Nucleus 327
 - Types of Radioactive Decay 328
 - Radioactive Decay Series 329
- 13.2 Measurement of Radiation 331
 - Measurement Methods 331
- A Closer Look: How Is Half-Life Determined? 332**
- Radiation Units 332*
- A Closer Look: Carbon Dating 333**
- Radiation Exposure 334*
- 13.3 Nuclear Energy 334
- A Closer Look: Radiation and Food Preservation 335**
- A Closer Look: Nuclear Medicine 336**
 - Nuclear Fission 336
 - Nuclear Power Plants 339
- A Closer Look: Three Mile Island and Chernobyl 342**
 - Nuclear Fusion 342
- A Closer Look: Nuclear Waste 344**
- Science and Society: High-Level Nuclear Waste 345**
 - The Source of Nuclear Energy 345
- People Behind the Science: Marie Curie 346**
- Summary 346*
- Key Terms 347*
- Applying the Concepts 347*
- Questions for Thought 349*
- For Further Analysis 350*
- Invitation to Inquiry 350*
- Parallel Exercises 350*

ASTRONOMY

14 The Universe 351



- 14.1 The Night Sky 352
- 14.2 Stars 354
 - Origin of Stars 354

- Brightness of Stars 355
- Star Temperature 356
- Star Types 358
- The Life of a Star 358
- Science and Society: Light Pollution 361**
- 14.3 Galaxies 362
 - The Milky Way Galaxy 362
 - Other Galaxies 362
- A Closer Look: Extraterrestrials? 364**
- The Life of a Galaxy 364*
- A Closer Look: Redshift and Hubble's Law 365**
- A Closer Look: Dark Energy 367**
- A Closer Look: Dark Matter 368**
- People Behind the Science: Jocelyn (Susan) Bell Burnell 369**
- Summary 370*
- Key Terms 370*
- Applying the Concepts 370*
- Questions for Thought 373*
- For Further Analysis 373*
- Invitation to Inquiry 373*
- Parallel Exercises 374*

15 The Solar System 377



- 15.1 Planets, Moons, and Other Bodies 378
 - Mercury 379
 - Venus 380
 - Mars 382
- Science and Society: Worth the Cost? 384**
 - Jupiter 385
 - Saturn 387
 - Uranus and Neptune 388
- 15.2 Small Bodies of the Solar System 388
 - Comets 389
 - Asteroids 391
 - Meteors and Meteorites 392
- 15.3 Origin of the Solar System 393
 - Stage A 393
 - Stage B 394
 - Stage C 394
- 15.4 Ideas About the Solar System 395
 - The Geocentric Model 395
 - The Heliocentric Model 396
- People Behind the Science: Gerard Peter Kuiper 398**
- Summary 400*

Key Terms 400
Applying the Concepts 400
Questions for Thought 402
For Further Analysis 403
Invitation to Inquiry 403
Parallel Exercises 403

16 Earth in Space 405



- 16.1 Shape and Size of Earth 406
 16.2 Motions of Earth 408
 Revolution 408
 Rotation 410
 Precession 411
 16.3 Place and Time 411
 Identifying Place 411
 Measuring Time 413
Science and Society:
Saving Time? 417
 16.4 The Moon 419
 Composition and
 Features 419
 History of the Moon 422
 16.5 The Earth-Moon System 422
 Phases of the Moon 423
 Eclipses of the Sun and
 Moon 423
 Tides 424
People Behind the Science:
Carl Edward Sagan 425
Summary 426
Key Terms 427
Applying the Concepts 427
Questions for Thought 430
For Further Analysis 430
Invitation to Inquiry 431
Parallel Exercises 431

EARTH SCIENCE

17 Rocks and Minerals 433



- 17.1 Solid Earth Materials 434
 17.2 Minerals 435
 Crystal Structures 435
 Silicates and Nonsilicates 436
 Physical Properties
 of Minerals 437

- 17.3 Mineral-Forming Processes 440
 17.4 Rocks 441
 Igneous Rocks 441
**Science and Society: Costs of
 Mining Mineral Resources 443**
A Closer Look: Asbestos 444
 Sedimentary Rocks 444
 Metamorphic Rocks 446
**Science and Society: Using
 Mineral Resources 447**
People Behind the Science:
Victor Moritz Goldschmidt 448
 17.5 The Rock Cycle 448
Summary 449
Key Terms 449
Applying the Concepts 450
Questions for Thought 452
For Further Analysis 452
Invitation to Inquiry 452
Parallel Exercises 452

18 Plate Tectonics 455



- 18.1 History of Earth's Interior 456
 18.2 Earth's Internal Structure 457
 The Crust 458
 The Mantle 459
 The Core 459
 A More Detailed
 Structure 460
**A Closer Look: Seismic
 Tomography 461**
 18.3 Theory of Plate Tectonics 461
 Evidence from Earth's
 Magnetic Field 461
 Evidence from the
 Ocean 462
 Lithosphere Plates and
 Boundaries 464
**A Closer Look: Measuring Plate
 Movement 466**
 Present-Day
 Understandings 467
People Behind the Science:
Harry Hammond Hess 469
Science and Society:
Geothermal Energy 470
Summary 471
Key Terms 472
Applying the Concepts 472
Questions for Thought 474
For Further Analysis 475
Invitation to Inquiry 475
Parallel Exercises 475

19 Building Earth's Surface 477



- 19.1 Interpreting Earth's
 Surface 478
 19.2 Diastrophism 479
 Stress and Strain 479
 Folding 480
 Faulting 482
 19.3 Earthquakes 484
 Causes of Earthquakes 484
 Locating and Measuring
 Earthquakes 484
 Measuring Earthquake
 Strength 487
**A Closer Look: Earthquake
 Safety 488**
 19.4 Origin of Mountains 489
 Folded and Faulted
 Mountains 489
 Volcanic Mountains 489
**A Closer Look: Volcanoes Change
 the World 493**
People Behind the Science:
James Hutton 494
Summary 494
Key Terms 495
Applying the Concepts 495
Questions for Thought 497
For Further Analysis 498
Invitation to Inquiry 498
Parallel Exercises 498

20 Shaping Earth's Surface 501



- 20.1 Weathering, Erosion, and
 Transportation 502
 20.2 Weathering 502
 20.3 Soils 506
 20.4 Erosion 506
 Mass Movement 507
 Running Water 508
 Glaciers 510
 Wind 512
Science and Society:
Acid Rain 513
People Behind the Science:
John Wesley Powell 514

- 20.5 Development of Landscapes 514
 Rock Structure 514
 Weathering and Erosion Processes 515
 Stage of Development 515
Summary 516
Key Terms 516
Applying the Concepts 516
Questions for Thought 518
For Further Analysis 519
Invitation to Inquiry 519
Parallel Exercises 519

21 Geologic Time 521



- 21.1 Fossils 522
 Early Ideas About Fossils 522
 Types of Fossilization 523
 21.2 Reading Rocks 525
 Arranging Events in Order 526
 Correlation 527
 21.3 Geologic Time 529
 Early Attempts at Earth Dating 529
 Modern Techniques 530
 The Geologic Time Scale 530
 Geologic Periods and Typical Fossils 531
 Mass Extinctions 533

People Behind the Science: Eduard Suess 534

- Interpreting Geologic History—A Summary 535
Summary 535
Key Terms 535
Applying the Concepts 536
Questions for Thought 538
For Further Analysis 538
Invitation to Inquiry 538
Parallel Exercises 538

22 The Atmosphere of Earth 541



- 22.1 The Atmosphere 542
 Composition of the Atmosphere 543
 Atmospheric Pressure 544

- Warming the Atmosphere 545
A Closer Look: Hole in the Ozone Layer? 546
 Structure of the Atmosphere 547
 22.2 The Winds 548
 Local Wind Patterns 549
A Closer Look: The Windchill Factor 550
Science and Society: Use Wind Energy? 551

- Global Wind Patterns 552
 22.3 Water and the Atmosphere 553
 Evaporation and Condensation 553
 Fog and Clouds 557

People Behind the Science: James Ephraim Lovelock 558

- Summary* 560
Key Terms 560
Applying the Concepts 560
Questions for Thought 563
For Further Analysis 563
Invitation to Inquiry 563
Parallel Exercises 563

23 Weather and Climate 565



- 23.1 Clouds and Precipitation 566
 Cloud-Forming Processes 566
 Origin of Precipitation 569
 23.2 Weather Producers 569
 Air Masses 570
 Weather Fronts 570

Science and Society: Urban Heat Islands 573

- Waves and Cyclones 574
 Major Storms 575
 23.3 Weather Forecasting 579
 23.4 Climate 580
 Major Climate Groups 580
 Regional Climate Influence 582
 Describing Climates 583

A Closer Look: El Niño and La Niña 586

- 23.5 Climate Change 587
 Causes of Global Climate Change 588
 Global Warming 588

People Behind the Science: Vilhelm Firman Koren Bjerknes 590

- Summary* 591
Key Terms 591
Applying the Concepts 591
Questions for Thought 594
For Further Analysis 594
Invitation to Inquiry 594
Parallel Exercises 594

24 Earth's Waters 597



- 24.1 Water on Earth 598
 Freshwater 599

Science and Society: Water Quality 600

- Surface Water 600
 Groundwater 602
 Freshwater as a Resource 603

A Closer Look: Water Quality and Wastewater Treatment 604

- 24.2 Seawater 606
 Oceans and Seas 607
 The Nature of Seawater 608
 Movement of Seawater 609

A Closer Look: Estuary Pollution 610

- A Closer Look: Health of the Chesapeake Bay 612**
A Closer Look: Rogue Waves 613

People Behind the Science: Rachel Louise Carson 616

- 24.3 The Ocean Floor 616
Summary 618
Key Terms 618
Applying the Concepts 618
Questions for Thought 621
For Further Analysis 621
Invitation to Inquiry 621
Parallel Exercises 621

Appendix A 623

Appendix B 631

Appendix C 632

Appendix D 633

Appendix E 643

Credits 699

Index 701