

CONTENTS

Preface ix

Prologue: Getting Started 2

Why Learn Physics? 3

What Is Physics? 4

How Is Physics Done? 5

How Does One Learn Physics? 6

Physical Quantities and Measurement 9

■ Physics Potpourri: The Metric System: “For All People, for All Time.” 11

CHAPTER 1

The Study of Motion 12

Drag Racing 12

1.1 Fundamental Physical Quantities 13

■ Physics Potpourri: Time Out! 16

1.2 Speed and Velocity 18

Vector Addition 23

1.3 Acceleration 26

Centripetal Acceleration 28

1.4 Simple Types of Motion 31

Zero Velocity 31

Constant Velocity 31

Constant Acceleration 33

■ Physics Family Album 38

Aristotle 38

Galileo 39

Summary 40 • Important Equations 41 • Mapping It Out! 41 • Questions 42 • Problems 42 • Challenges 45

CHAPTER 2

Newton’s Laws 46

New Horizons—Old Physics 46

2.1 Force 47

2.2 Newton’s First Law of Motion 51

■ Physics Potpourri: Friction: A Sticky Subject 52

2.3 Mass 55

2.4 Newton’s Second Law of Motion 57

2.5 The International System of Units (SI) 60

2.6 Examples: Different Forces, Different Motions 60

Simple Harmonic Motion 62

Falling Body with Air Resistance 64

2.7 Newton’s Third Law of Motion 67

2.8 The Law of Universal Gravitation 70

Orbits 73

Gravitational Field 74

■ Physics Potpourri: Hooke-d! 76

2.9 Tides 77

■ Physics Family Album 80

Summary 80 • Important Equations 82 • Mapping It Out! 82 • Questions 83 • Problems 84 • Challenges 85

CHAPTER 3

Energy and Conservation Laws 86

Forensic Physics 86

3.1 Conservation Laws 87

3.2 Linear Momentum 88

3.3 Work: The Key to Energy 94

3.4 Energy 99

3.5 The Conservation of Energy 104

3.6 Collisions: An Energy Point of View 111

■ Physics Potpourri: Energy Conservation, Consumption, and Crisis 112

3.7 Power 115

3.8 Rotation and Angular Momentum 118

■ Physics Potpourri: *Starquakes: A Glitch in Time* 120

■ Physics Family Album 123

Summary 124 • Important Equations 124 • Mapping

It Out! 124 • Questions 124 • Problems 125 •

Challenges 127

CHAPTER 4

Physics of Matter 128

Airships 128

4.1 Matter: Phases, Forms, and Forces 128

Behavior of Atoms and Molecules 133

■ Physics Potpourri: What’s in a Name? 136

4.2 Pressure 138

4.3 Density 143

4.4 Fluid Pressure and Gravity 147

Fluid Pressure in the Atmosphere 150

4.5 Archimedes’ Principle 153

■ Physics Potpourri: Superfluids—Friction-free Flow 156

4.6 Pascal’s Principle 161

4.7 Bernoulli’s Principle 162

■ Physics Family Album 165

Fluids 165

Summary 167 • Important Equations 167 • Mapping

It Out! 167 • Questions 168 • Problems 169 •

Challenges 171

CHAPTER 5

Temperature and Heat 172

Hurricanes 172

5.1 Temperature 173

■ Physics Potpourri: To Breathe or Not to Breathe, That Is the Question 176

5.2 Thermal Expansion 178

Liquids 181

Gases 182

5.3 The First Law of Thermodynamics 184

5.4 Heat Transfer 188

Conduction 188

Convection 189

- Radiation 190
- Combinations 191
- 5.5 Specific Heat Capacity 193**
 - Physics Potpourri: Energy Flow in Stars 194
- 5.6 Phase Transitions 198**
 - Humidity 201
- 5.7 Heat Engines and The Second Law of Thermodynamics 204**
 - Heat Movers 207
 - Usable Energy 209
 - Physics Family Album 211
 - Heat 211
 - Summary 213 • Important Equations 213 • Mapping It Out! 213 • Questions 214 • Problems 215 • Challenges 217

CHAPTER 6

Waves and Sound 218

- Sound Medicine 218
- 6.1 Waves—Types and Properties 219**
- 6.2 Aspects of Wave Propagation 227**
 - Reflection 228
 - Physics Potpourri: The Hubble Relation—Expanding Our Horizons 230
 - Doppler Effect 230
 - Bow Waves and Shock Waves 233
 - Diffraction 233
 - Interference 235
- 6.3 Sound 237**
 - Sound Applications 239
 - Physics Potpourri: Putting Sound to Work 240
- 6.4 Production of Sound 242**
- 6.5 Propagation of Sound 245**
- 6.6 Perception of Sound 248**
 - Pitch 248
 - Loudness 248
 - Tone Quality 251
 - Physics Family Album 254
 - Sound 254
 - Summary 255 • Important Equations 256 • Mapping It Out! 256 • Questions 256 • Problems 257 • Challenges 259

CHAPTER 7

Electricity 260

- iProducts: iPods, iPhones, and iPads 260
- 7.1 Electric Charge 261**
- 7.2 Electric Force and Coulomb's Law 263**
 - Physics Potpourri: Electrifying Sights and Sounds: A Thunderstorm Primer 268
- 7.3 Electric Currents—Superconductivity 271**
 - Resistance 272
 - Superconductivity 273
- 7.4 Electric Circuits and Ohm's Law 274**
 - Series and Parallel Circuits 276
 - Physics Potpourri: Electricity and the Human Body 278
- 7.5 Power and Energy in Electric Currents 280**

- 7.6 AC and DC 283**
 - Physics Family Album 285
 - Summary 287 • Important Equations 287 • Mapping It Out! 288 • Questions 288 • Problems 289 • Challenges 291

CHAPTER 8

Electromagnetism and EM Waves 292

- Metal Detectors 292
- 8.1 Magnetism 293**
- 8.2 Interactions between Electricity and Magnetism 297**
- 8.3 Principles of Electromagnetism 304**
- 8.4 Applications to Sound Reproduction 306**
 - Digital Sound 309
- 8.5 Electromagnetic Waves 310**
 - Radio Waves 312
 - Microwaves 313
 - Infrared 314
 - Visible Light 314
 - Ultraviolet Radiation 315
 - X-Rays 315
 - Physics Potpourri: N Rays: "C'est une erreur." 316
 - Gamma Rays 317
- 8.6 Blackbody Radiation 318**
 - Temperature Measurement 320
 - Detection of Warm Objects 321
 - Physics Potpourri: Cosmic Background Radiation (CBR)—A Relic of the Big Bang 322
- 8.7 EM Waves and Earth's Atmosphere 325**
 - Ozone Layer 325
 - Greenhouse Effect 326
 - The Ionosphere 327
 - Astronomy 327
 - Physics Family Album 329
 - Summary 332 • Important Equations 332 • Mapping It Out! 332 • Questions 333 • Problems 334 • Challenges 335

CHAPTER 9

Optics 336

- Doggone It! 336
- 9.1 Light Waves 336**
 - Reflection 337
 - Diffraction 339
 - Interference 340
 - Polarization 342
- 9.2 Mirrors: Plane and Not So Simple 345**
 - "One-Way Mirror" 346
 - Curved Mirrors 347
 - Astronomical Telescope Mirrors 349
- 9.3 Refraction 353**
 - Total Internal Reflection 356
- 9.4 Lenses and Images 359**
 - Physics Potpourri: Fresnel, Pharos, and Physics 360

Image Formation 363

Magnification 366

Aberrations 367

■ **Physics Potpourri: The *Camera Obscura*:
A Room with a View** 368

9.5 The Human Eye 370

Eye Surgery 373

9.6 Dispersion and Color 373

9.7 Atmospheric Optics: Rainbows, Halos, and Blue Skies 375

Rainbows 375

Halos 378

Blue Skies 379

■ **Physics Family Album** 381

Summary 384 • Important Equations 384 • Mapping
It Out! 384 • Questions 385 • Problems 387 •
Challenges 388

CHAPTER 10

Atomic Physics 390

Something Old, Something New 390

10.1 The Quantum Hypothesis 390

Blackbody Radiation 391

10.2 The Photoelectric Effect and Photons 394

10.3 Atomic Spectra 398

■ **Physics Potpourri: Cosmic Chemistry, “. . . To Dream
of Such a Thing.”** 400

10.4 The Bohr Model of the Atom 400

10.5 Quantum Mechanics 405

10.6 Atomic Structure 409

10.7 X-Ray Spectra 417

10.8 Lasers 418

■ **Physics Potpourri: Holograms—3-D Images,
No Glasses Required** 420

■ **Physics Family Album** 424

Summary 425 • Important Equations 426 • Mapping
It Out! 426 • Questions 426 • Problems 427 •
Challenges 429

CHAPTER 11

Nuclear Physics 430

Radioactive Sentinel 430

11.1 The Nucleus 430

11.2 Radioactivity 434

Alpha Decay 435

Beta Decay 436

Gamma Decay 437

Radioactivity and Energy 438

Applications 438

11.3 Half-Life 440

Dating 443

■ **Physics Potpourri: Radiation: A Killer Turned
Lifesaver** 444

11.4 Artificial Nuclear Reactions 445

11.5 Nuclear Binding Energy 446

11.6 Nuclear Fission 449

Atomic Bombs 450

Nuclear Power Plants 451

11.7 Nuclear Fusion 454

Fusion in Stars 455

■ **Physics Potpourri: Big Bang Nucleosynthesis** 456

Thermonuclear Weapons 458

Controlled Fusion 458

Cold Fusion 460

■ **Physics Family Album** 461

Summary 464 • Important Equations 464 • Mapping
It Out! 464 • Questions 464 • Problems 466 •
Challenges 467

CHAPTER 12

Special Relativity and Elementary Particles 468

Antimatter: Available at a Medical Facility near You 468

12.1 Special Relativity: The Physics of High Velocity 469

Postulates of Special Relativity 469

Predictions of Special Relativity 470

12.2 Forces and Particles 476

The Four Forces: Natural Interactions among Particles 476

Classification Schemes for Particles 478

Spin 479

Elementary Particle Lexicon 481

12.3 Conservation Laws, Revisited 483

New Conservation Laws 484

Conservation of Baryon and Lepton Numbers 484

■ **Physics Potpourri: Symmetry and Conservation
Laws** 486

Conservation of Strangeness 488

■ **Physics Potpourri: Does Nature Distinguish
Left from Right?** 490

12.4 Quarks: Order Out of Chaos 492

Quarks 494

12.5 The Standard Model and GUTs 498

Charm, Truth, and Beauty 500

The Electroweak Interaction and GUTs 503

■ **Physics Family Album** 506

Summary 507 • Important Equations 508 • Mapping
It Out! 508 • Questions 509 • Problems 510 •
Challenges 511

Epilogue 512

General Relativity 514

Cosmology 519

Appendixes

A Winners of the Nobel Prize in Physics A-1

B Math Review B-1

C Answers C-1

Glossary G-1

Index I-1

Table of Conversion Factors and
Other Information Inside back cover

Periodic Table Inside back cover