

Brief Contents

Chapter 1 Introduction 1

PART ONE

Mechanics

Chapter 2 Motion Along a Line 25
Chapter 3 Motion in a Plane 55
Chapter 4 Force and Newton's Laws of Motion 87
Chapter 5 Circular Motion 146
Chapter 6 Conservation of Energy 186
Chapter 7 Linear Momentum 225
Chapter 8 Torque and Angular Momentum 260
Chapter 9 Fluids 316
Chapter 10 Elasticity and Oscillations 356
Chapter 11 Waves 392
Chapter 12 Sound 420

PART TWO

Thermal Physics

Chapter 13 Temperature and Ideal Gas 457
Chapter 14 Heat 489
Chapter 15 Thermodynamics 527

PART THREE

Electromagnetism

Chapter 16 Electric Forces and Fields 561
Chapter 17 Electric Potential 601
Chapter 18 Electric Current and Circuits 640
Chapter 19 Magnetic Forces and Fields 693
Chapter 20 Electromagnetic Induction 741
Chapter 21 Alternating Current 780

PART FOUR

Electromagnetic Waves and Optics

Chapter 22 Electromagnetic Waves 811
Chapter 23 Reflection and Refraction of Light 848
Chapter 24 Optical Instruments 891
Chapter 25 Interference and Diffraction 922

PART FIVE

Quantum and Particle Physics and Relativity

Chapter 26 Relativity 967
Chapter 27 Early Quantum Physics and the Photon 997
Chapter 28 Quantum Physics 1030
Chapter 29 Nuclear Physics 1065
Chapter 30 Particle Physics 1105

Appendix A Mathematics Review A-1

Appendix B Table of Selected Nuclides A-15

Contents

List of Selected Applications x

Preface xiii

To the Student xxii

Acknowledgments xxx

Chapter 1 Introduction 1

- 1.1 Why Study Physics? 2
- 1.2 Talking Physics 2
- 1.3 The Use of Mathematics 3
- 1.4 Scientific Notation and Significant Figures 5
- 1.5 Units 8
- 1.6 Dimensional Analysis 11
- 1.7 Problem-Solving Techniques 13
- 1.8 Approximation 14
- 1.9 Graphs 15

PART ONE

Mechanics

Chapter 2 Motion Along a Line 25

- 2.1 Position and Displacement 26
- 2.2 Velocity: Rate of Change of Position 28
- 2.3 Acceleration: Rate of Change of Velocity 33
- 2.4 Motion Along a Line with Constant Acceleration 37
- 2.5 Visualizing Motion Along a Line with Constant Acceleration 40
- 2.6 Free Fall 43

Chapter 3 Motion in a Plane 55

- 3.1 Graphical Addition and Subtraction of Vectors 56
- 3.2 Vector Addition and Subtraction Using Components 59
- 3.3 Velocity 63
- 3.4 Acceleration 64
- 3.5 Motion in a Plane with Constant Acceleration 67
- 3.6 Velocity Is Relative; Reference Frames 73

Chapter 4 Force and Newton's Laws of Motion 87

- 4.1 Force 88
- 4.2 Inertia and Equilibrium: Newton's First Law of Motion 92
- 4.3 Net Force, Mass, and Acceleration: Newton's Second Law of Motion 96
- 4.4 Interaction Pairs: Newton's Third Law of Motion 97
- 4.5 Gravitational Forces 99
- 4.6 Contact Forces 102
- 4.7 Tension 109
- 4.8 Applying Newton's Second Law 113
- 4.9 Reference Frames 122
- 4.10 Apparent Weight 123
- 4.11 Air Resistance 126
- 4.12 Fundamental Forces 126

Chapter 5 Circular Motion 146

- 5.1 Description of Uniform Circular Motion 147
- 5.2 Radial Acceleration 152
- 5.3 Unbanked and Banked Curves 157
- 5.4 Circular Orbits of Satellites and Planets 160
- 5.5 Nonuniform Circular Motion 164
- 5.6 Tangential and Angular Acceleration 168
- 5.7 Apparent Weight and Artificial Gravity 170

Review & Synthesis: Chapters 1–5 182

Chapter 6 Conservation of Energy 186

- 6.1 The Law of Conservation of Energy 187
- 6.2 Work Done by a Constant Force 188
- 6.3 Kinetic Energy 195
- 6.4 Gravitational Potential Energy (1) 197
- 6.5 Gravitational Potential Energy (2) 202
- 6.6 Work Done by Variable Forces: Hooke's Law 205
- 6.7 Elastic Potential Energy 208
- 6.8 Power 212

Chapter 7 Linear Momentum 225

- 7.1** Conservation Law for a Vector Quantity 226
- 7.2** Momentum 226
- 7.3** The Impulse-Momentum Theorem 228
- 7.4** Conservation of Momentum 234
- 7.5** Center of Mass 237
- 7.6** Motion of the Center of Mass 240
- 7.7** Collisions in One Dimension 242
- 7.8** Collisions in Two Dimensions 247

Chapter 8 Torque and Angular Momentum 260

- 8.1** Rotational Kinetic Energy and Rotational Inertia 261
- 8.2** Torque 266
- 8.3** Calculating Work Done from a Torque 271
- 8.4** Rotational Equilibrium 273
- 8.5** Equilibrium in the Human Body 281
- 8.6** Rotational Form of Newton's Second Law 285
- 8.7** The Motion of Rolling Objects 286
- 8.8** Angular Momentum 289
- 8.9** The Vector Nature of Angular Momentum 293

Review & Synthesis: Chapters 6–8 311

Chapter 9 Fluids 316

- 9.1** States of Matter 317
- 9.2** Pressure 317
- 9.3** Pascal's Principle 320
- 9.4** The Effect of Gravity on Fluid Pressure 321
- 9.5** Measuring Pressure 324
- 9.6** The Buoyant Force 327
- 9.7** Fluid Flow 332
- 9.8** Bernoulli's Equation 334
- 9.9** Viscosity 338
- 9.10** Viscous Drag 341
- 9.11** Surface Tension 343

Chapter 10 Elasticity and Oscillations 356

- 10.1** Elastic Deformations of Solids 357
- 10.2** Hooke's Law for Tensile and Compressive Forces 357

- 10.3** Beyond Hooke's Law 360
- 10.4** Shear and Volume Deformations 363
- 10.5** Simple Harmonic Motion 367
- 10.6** The Period and Frequency for SHM 370
- 10.7** Graphical Analysis of SHM 374
- 10.8** The Pendulum 376
- 10.9** Damped Oscillations 380
- 10.10** Forced Oscillations and Resonance 380

Chapter 11 Waves 392

- 11.1** Waves and Energy Transport 393
- 11.2** Transverse and Longitudinal Waves 395
- 11.3** Speed of Transverse Waves on a String 397
- 11.4** Periodic Waves 398
- 11.5** Mathematical Description of a Wave 400
- 11.6** Graphing Waves 401
- 11.7** Principle of Superposition 403
- 11.8** Reflection and Refraction 404
- 11.9** Interference and Diffraction 406
- 11.10** Standing Waves 409

Chapter 12 Sound 420

- 12.1** Sound Waves 421
- 12.2** The Speed of Sound Waves 423
- 12.3** Amplitude and Intensity of Sound Waves 425
- 12.4** Standing Sound Waves 429
- 12.5** Timbre 433
- 12.6** The Human Ear 435
- 12.7** Beats 437
- 12.8** The Doppler Effect 439
- 12.9** Echolocation and Medical Imaging 443

Review & Synthesis: Chapters 9–12 453

PART TWO**Thermal Physics****Chapter 13** Temperature and the Ideal Gas 457

- 13.1** Temperature and Thermal Equilibrium 458
- 13.2** Temperature Scales 459
- 13.3** Thermal Expansion of Solids and Liquids 460

- 13.4** Molecular Picture of a Gas 464
- 13.5** Absolute Temperature and the Ideal Gas Law 466
- 13.6** Kinetic Theory of the Ideal Gas 471
- 13.7** Temperature and Reaction Rates 475
- 13.8** Diffusion 477

Chapter 14 Heat 489

- 14.1** Internal Energy 490
- 14.2** Heat 492
- 14.3** Heat Capacity and Specific Heat 494
- 14.4** Specific Heat of Ideal Gases 498
- 14.5** Phase Transitions 500
- 14.6** Thermal Conduction 506
- 14.7** Thermal Convection 510
- 14.8** Thermal Radiation 511

Chapter 15 Thermodynamics 527

- 15.1** The First Law of Thermodynamics 528
- 15.2** Thermodynamic Processes 530
- 15.3** Thermodynamic Processes for an Ideal Gas 533
- 15.4** Reversible and Irreversible Processes 536
- 15.5** Heat Engines 537
- 15.6** Refrigerators and Heat Pumps 540
- 15.7** Reversible Engines and Heat Pumps 542
- 15.8** Entropy 546
- 15.9** The Third Law of Thermodynamics 549

Review & Synthesis: Chapters 13–15 557

PART THREE

Electromagnetism

Chapter 16 Electric Forces and Fields 561

- 16.1** Electric Charge 562
- 16.2** Electric Conductors and Insulators 565
- 16.3** Coulomb's Law 570
- 16.4** The Electric Field 573
- 16.5** Motion of a Point Charge in a Uniform Electric Field 581
- 16.6** Conductors in Electrostatic Equilibrium 584
- 16.7** Gauss's Law for Electric Fields 587

Chapter 17 Electric Potential 601

- 17.1** Electric Potential Energy 602
- 17.2** Electric Potential 605
- 17.3** The Relationship Between Electric Field and Potential 612
- 17.4** Conservation of Energy for Moving Charges 616
- 17.5** Capacitors 617
- 17.6** Dielectrics 621
- 17.7** Energy Stored in a Capacitor 626

Chapter 18 Electric Current and Circuits 640

- 18.1** Electric Current 641
- 18.2** Emf and Circuits 643
- 18.3** Microscopic View of Current in a Metal: The Free-Electron Model 645
- 18.4** Resistance and Resistivity 648
- 18.5** Kirchhoff's Rules 654
- 18.6** Series and Parallel Circuits 655
- 18.7** Circuit Analysis Using Kirchhoff's Rules 661
- 18.8** Power and Energy in Circuits 664
- 18.9** Measuring Currents and Voltages 666
- 18.10** RC Circuits 668
- 18.11** Electrical Safety 672

Review & Synthesis: Chapters 16–18 688

Chapter 19 Magnetic Forces and Fields 693

- 19.1** Magnetic Fields 694
- 19.2** Magnetic Force on a Point Charge 697
- 19.3** Charged Particle Moving Perpendicularly to a Uniform Magnetic Field 703
- 19.4** Motion of a Charged Particle in a Uniform Magnetic Field: General 707
- 19.5** A Charged Particle in Crossed \vec{E} and \vec{B} Fields 708
- 19.6** Magnetic Force on a Current-Carrying Wire 713
- 19.7** Torque on a Current Loop 715
- 19.8** Magnetic Field due to an Electric Current 718
- 19.9** Ampère's Law 723
- 19.10** Magnetic Materials 725

Chapter 20 Electromagnetic Induction 741

- 20.1 Motional Emf 742
- 20.2 Electric Generators 745
- 20.3 Faraday's Law 748
- 20.4 Lenz's Law 753
- 20.5 Back Emf in a Motor 756
- 20.6 Transformers 756
- 20.7 Eddy Currents 758
- 20.8 Induced Electric Fields 759
- 20.9 Inductance 761
- 20.10 *LR* Circuits 765

Chapter 21 Alternating Current 780

- 21.1 Sinusoidal Currents and Voltages; Resistors in ac Circuits 781
- 21.2 Electricity in the Home 783
- 21.3 Capacitors in ac Circuits 785
- 21.4 Inductors in ac Circuits 788
- 21.5 *RLC* Series Circuits 790
- 21.6 Resonance in an *RLC* Circuit 794
- 21.7 Converting ac to dc; Filters 796

Review & Synthesis: Chapters 19–21 807

PART FOUR

Electromagnetic Waves and Optics

Chapter 22 Electromagnetic Waves 811

- 22.1 Maxwell's Equations and Electromagnetic Waves 812
- 22.2 Antennas 813
- 22.3 The Electromagnetic Spectrum 816
- 22.4 Speed of EM Waves in Vacuum and in Matter 821
- 22.5 Characteristics of Traveling Electromagnetic Waves in Vacuum 824
- 22.6 Energy Transport by EM Waves 827
- 22.7 Polarization 830
- 22.8 The Doppler Effect for EM Waves 838

Chapter 23 Reflection and Refraction of Light 848

- 23.1 Wavefronts, Rays, and Huygens's Principle 849
- 23.2 The Reflection of Light 852
- 23.3 The Refraction of Light: Snell's Law 853
- 23.4 Total Internal Reflection 858
- 23.5 Polarization by Reflection 864
- 23.6 The Formation of Images Through Reflection or Refraction 865
- 23.7 Plane Mirrors 867
- 23.8 Spherical Mirrors 869
- 23.9 Thin Lenses 876

Chapter 24 Optical Instruments 891

- 24.1 Lenses in Combination 892
- 24.2 Cameras 895
- 24.3 The Eye 898
- 24.4 Angular Magnification and the Simple Magnifier 903
- 24.5 Compound Microscopes 905
- 24.6 Telescopes 907
- 24.7 Aberrations of Lenses and Mirrors 911

Chapter 25 Interference and Diffraction 922

- 25.1 Constructive and Destructive Interference 923
- 25.2 The Michelson Interferometer 927
- 25.3 Thin Films 929
- 25.4 Young's Double-Slit Experiment 935
- 25.5 Gratings 939
- 25.6 Diffraction and Huygens's Principle 942
- 25.7 Diffraction by a Single Slit 945
- 25.8 Diffraction and the Resolution of Optical Instruments 947
- 25.9 X-Ray Diffraction 950
- 25.10 Holography 952

Review & Synthesis: Chapters 22–25 963

PART FIVE

Quantum and Particle Physics and Relativity

Chapter 26 Relativity 967

- 26.1 Postulates of Relativity 968
- 26.2 Simultaneity and Ideal Observers 971
- 26.3 Time Dilation 974
- 26.4 Length Contraction 977
- 26.5 Velocities in Different Reference Frames 979
- 26.6 Relativistic Momentum 981
- 26.7 Mass and Energy 983
- 26.8 Relativistic Kinetic Energy 985

Chapter 27 Early Quantum Physics and the Photon 997

- 27.1 Quantization 998
- 27.2 Blackbody Radiation 998
- 27.3 The Photoelectric Effect 1000
- 27.4 X-Ray Production 1005
- 27.5 Compton Scattering 1006
- 27.6 Spectroscopy and Early Models
of the Atom 1009
- 27.7 The Bohr Model of the Hydrogen Atom;
Atomic Energy Levels 1012
- 27.8 Pair Annihilation and Pair Production 1020

Chapter 28 Quantum Physics 1030

- 28.1 The Wave-Particle Duality 1031
- 28.2 Matter Waves 1032
- 28.3 Electron Microscopes 1036
- 28.4 The Uncertainty Principle 1037
- 28.5 Wave Functions for a Confined Particle 1040
- 28.6 The Hydrogen Atom: Wave Functions and
Quantum Numbers 1042
- 28.7 The Exclusion Principle; Electron
Configurations for Atoms Other than
Hydrogen 1044
- 28.8 Electron Energy Levels in a Solid 1048
- 28.9 Lasers 1049
- 28.10 Tunneling 1053

Chapter 29 Nuclear Physics 1065

- 29.1 Nuclear Structure 1066
- 29.2 Binding Energy 1069
- 29.3 Radioactivity 1073
- 29.4 Radioactive Decay Rates
and Half-Lives 1079
- 29.5 Biological Effects of Radiation 1085
- 29.6 Induced Nuclear Reactions 1090
- 29.7 Fission 1091
- 29.8 Fusion 1096

Chapter 30 Particle Physics 1105

- 30.1 Fundamental Particles 1106
- 30.2 Fundamental Interactions 1108
- 30.3 Unification 1111
- 30.4 Particle Accelerators 1113
- 30.5 Twenty-First-Century Particle Physics 1114

Review & Synthesis: Chapters 26–30 1118

Appendix A

Mathematics Review A–1

Appendix B

Table of Selected Nuclides A–15

Answers to Selected Questions and Problems AP–1

Credits C–1

Index I–1