VOLUME TWO

Chapters 20–39

Essential University Physics

FOURTH EDITION

GLOBAL EDITION

Richard Wolfson

Middlebury College

Pearson

Detailed Contents

Volume 1 contains Chapters 1–19

Volume 2 contains Chapters 20–39

Chapter 1 Doing Physics 17

1.1 Realms of Physics 17

1.2 Measurements and Units 18

1.3 Working with Numbers 21

1.4 Strategies for Learning Physics 24

PART ONE

Mechanics 31

Chapter 2 Motion in a Straight Line 32

2.1 Average Motion 32

2.2 Instantaneous Velocity 34

2.3 Acceleration 36

2.4 Constant Acceleration 38

2.5 The Acceleration of Gravity 41

2.6 When Acceleration Isn't Constant 43

Chapter 3 Motion in Two and Three Dimensions 50

3.1 Vectors 50

3.2 Velocity and Acceleration Vectors 53

3.3 Relative Motion 54

3.4 Constant Acceleration 56

3.5 Projectile Motion 57

3.6 Uniform Circular Motion 62

Chapter 4 Force and Motion 70

4.1 The Wrong Question 70

4.2 Newton's First and Second Laws 71

4.3 Forces 75

4.4 The Force of Gravity 76

4.5 Using Newton's Second Law 78

4.6 Newton's Third Law 81

Chapter 5 Using Newton's Laws 90

5.1 Using Newton's Second Law 90

5.2 Multiple Objects 93

5.3 Circular Motion 95

5.4 Friction 99

5.5 Drag Forces 104

Chapter 6 Energy, Work, and Power 110

6.1 Energy 110

6.2 Work 112

6.3 Forces That Vary 115

6.4 Kinetic Energy 119

6.5 Power 121

Chapter 7 Conservation of Energy 129

7.1 Conservative and Nonconservative Forces 130

7.2 Potential Energy 131

7.3 Conservation of Mechanical Energy 135

7.4 Nonconservative Forces 138

7.5 Conservation of Energy 140

7.6 Potential-Energy Curves 141

Chapter 8 Gravity 150

8.1 Toward a Law of Gravity 150

8.2 Universal Gravitation 151

8.3 Orbital Motion 153

8.4 Gravitational Energy 156

8.5 The Gravitational Field 160

Chapter 9 Systems of Particles 166

9.1 Center of Mass 166

9.2 Momentum 172

9.3 Kinetic Energy of a System 176

9.4 Collisions 177

9.5 Totally Inelastic Collisions 178

9.6 Elastic Collisions 180

Chapter 10 Rotational Motion 191

10.1 Angular Velocity and Acceleration 191

10.2 Torque 194

10.3 Rotational Inertia and the Analog of Newton's Law 196

10.4 Rotational Energy 201
10.5 Rolling Motion 203

Chapter 11 Rotational Vectors and Angular Momentum 212

11.1 Angular Velocity and Acceleration Vectors 212
11.2 Torque and the Vector Cross Product 213
11.3 Angular Momentum 215
11.4 Conservation of Angular Momentum 217
11.5 Gyroscopes and Precession 219

Chapter 12 Static Equilibrium 227

12.1 Conditions for Equilibrium 227
12.2 Center of Gravity 229
12.3 Examples of Static Equilibrium 230
12.4 Stability 232

PART TWO
Oscillations, Waves, and Fluids 244

Chapter 13 Oscillatory Motion 245

13.1 Describing Oscillatory Motion 246
13.2 Simple Harmonic Motion 247
13.3 Applications of Simple Harmonic Motion 250
13.4 Circular Motion and Harmonic Motion 254
13.5 Energy in Simple Harmonic Motion 255
13.6 Damped Harmonic Motion 257
13.7 Driven Oscillations and Resonance 258

Chapter 14 Wave Motion 266

14.1 Waves and Their Properties 266
14.2 Wave Math 268
14.3 Waves on a String 270
14.4 Wave Energy 271
14.5 Sound Waves 273
14.6 Interference 274
14.7 Reflection and Refraction 277
14.8 Standing Waves 279
14.9 The Doppler Effect and Shock Waves 281

Chapter 15 Fluid Motion 290

15.1 Density and Pressure 290
15.2 Hydrostatic Equilibrium 291
15.3 Archimedes' Principle and Buoyancy 294
15.4 Fluid Dynamics 296
15.5 Applications of Fluid Dynamics 299
15.6 Viscosity and Turbulence 303

PART THREE
Thermodynamics 310

Chapter 16 Temperature and Heat 311

16.1 Heat, Temperature, and Thermodynamic Equilibrium 311
16.2 Heat Capacity and Specific Heat 313
16.3 Heat Transfer 315
16.4 Thermal-Energy Balance 321

Chapter 17 The Thermal Behavior of Matter 329

17.1 Gases 329
17.2 Phase Changes 334
17.3 Thermal Expansion 337

Chapter 18 Heat, Work, and the First Law of Thermodynamics 344

18.1 The First Law of Thermodynamics 344
18.2 Thermodynamic Processes 346
18.3 Specific Heats of an Ideal Gas 354

Chapter 19 The Second Law of Thermodynamics 361

19.1 Reversibility and Irreversibility 361
19.2 The Second Law of Thermodynamics 362
19.3 Applications of the Second Law 366
19.4 Entropy and Energy Quality 369

PART FOUR
Electromagnetism 383

Chapter 20 Electric Charge, Force, and Field 384

20.1 Electric Charge 384
20.2 Coulomb's Law 385
20.3 The Electric Field 389
20.4 Fields of Charge Distributions 391
20.5 Matter in Electric Fields 396

Chapter 21 Gauss's Law 405

21.1 Electric Field Lines 405
21.2 Electric Field and Electric Flux 407
21.3 Gauss's Law 410
21.4 Using Gauss's Law 412

21.5 Fields of Arbitrary Charge Distributions 419
21.6 Gauss's Law and Conductors 420

Chapter 22 Electric Potential 430
22.1 Electric Potential Difference 430
22.2 Calculating Potential Difference 434
22.3 Potential Difference and the Electric Field 440
22.4 Charged Conductors 443

Chapter 23 Electrostatic Energy and Capacitors 450
23.1 Electrostatic Energy 450
23.2 Capacitors 451
23.3 Using Capacitors 453
23.4 Energy in the Electric Field 457

Chapter 24 Electric Current 465
24.1 Electric Current 465
24.2 Conduction Mechanisms 468
24.3 Resistance and Ohm's Law 472
24.4 Electric Power 474
24.5 Electrical Safety 475

Chapter 25 Electric Circuits 483
25.1 Circuits, Symbols, and Electromotive Force 483
25.2 Series and Parallel Resistors 484
25.3 Kirchhoff's Laws and Multiloop Circuits 490
25.4 Electrical Measurements 492
25.5 Capacitors in Circuits 493

Chapter 26 Magnetism: Force and Field 504
26.1 What Is Magnetism? 504
26.2 Magnetic Force and Field 505
26.3 Charged Particles in Magnetic Fields 507
26.4 The Magnetic Force on a Current 509
26.5 Origin of the Magnetic Field 511
26.6 Magnetic Dipoles 514
26.7 Magnetic Matter 517
26.8 Ampère's Law 519

Chapter 27 Electromagnetic Induction 532
27.1 Induced Currents 532
27.2 Faraday's Law 534
27.3 Induction and Energy 538
27.4 Inductance 544
27.5 Magnetic Energy 549
27.6 Induced Electric Fields 552

Chapter 28 Alternating-Current Circuits 561
28.1 Alternating Current 561
28.2 Circuit Elements in AC Circuits 562
28.3 *LC* Circuits 566
28.4 Driven *RLC* Circuits and Resonance 569
28.5 Power in AC Circuits 572
28.6 Transformers and Power Supplies 573

Chapter 29 Maxwell's Equations and Electromagnetic Waves 580
29.1 The Four Laws of Electromagnetism 580
29.2 Ambiguity in Ampère's Law 581
29.3 Maxwell's Equations 583
29.4 Electromagnetic Waves 584
29.5 Properties of Electromagnetic Waves 588
29.6 The Electromagnetic Spectrum 592
29.7 Producing Electromagnetic Waves 593
29.8 Energy and Momentum in Electromagnetic Waves 594

PART FIVE
Optics 604

Chapter 30 Reflection and Refraction 605
30.1 Reflection 605
30.2 Refraction 607
30.3 Total Internal Reflection 609
30.4 Dispersion 611

Chapter 31 Images and Optical Instruments 619
31.1 Images with Mirrors 619
31.2 Images with Lenses 624
31.3 Refraction in Lenses: The Details 627
31.4 Optical Instruments 630

Chapter 32 Interference and Diffraction 640
32.1 Coherence and Interference 640
32.2 Double-Slit Interference 642
32.3 Multiple-Slit Interference and Diffraction Gratings 645
32.4 Interferometry 649

32.5 Huygens' Principle and Diffraction 651
32.6 The Diffraction Limit 654

PART SIX
Modern Physics 663

Chapter 33 Relativity 664
33.1 Speed *c* Relative to What? 665
33.2 Matter, Motion, and the Ether 665
33.3 Special Relativity 667
33.4 Space and Time in Relativity 668
33.5 Simultaneity Is Relative 673
33.6 The Lorentz Transformations 675
33.7 Energy and Momentum in Relativity 678
33.8 Electromagnetism and Relativity 682
33.9 General Relativity 683

Chapter 34 Particles and Waves 690
34.1 Toward Quantum Theory 690
34.2 Blackbody Radiation 691
34.3 Photons 693
34.4 Atomic Spectra and the Bohr Atom 696
34.5 Matter Waves 700
34.6 The Uncertainty Principle 702
34.7 Complementarity 704

Chapter 35 Quantum Mechanics 710
35.1 Particles, Waves, and Probability 711
35.2 The Schrödinger Equation 712
35.3 Particles and Potentials 714
35.4 Quantum Mechanics in Three Dimensions 721
35.5 Relativistic Quantum Mechanics 721

Chapter 36 Atomic Physics 727
36.1 The Hydrogen Atom 727
36.2 Electron Spin 731
36.3 The Exclusion Principle 734
36.4 Multielectron Atoms and the Periodic Table 735
36.5 Transitions and Atomic Spectra 739

Chapter 37 Molecules and Solids 746
37.1 Molecular Bonding 746
37.2 Molecular Energy Levels 748
37.3 Solids 751
37.4 Superconductivity 757

Chapter 38 Nuclear Physics 765
38.1 Elements, Isotopes, and Nuclear Structure 765
38.2 Radioactivity 770
38.3 Binding Energy and Nucleosynthesis 776
38.4 Nuclear Fission 778
38.5 Nuclear Fusion 784

Chapter 39 From Quarks to the Cosmos 793
39.1 Particles and Forces 793
39.2 Particles and More Particles 794
39.3 Quarks and the Standard Model 798
39.4 Unification 801
39.5 The Evolving Universe 803

APPENDICES
Appendix A Mathematics A-1
Appendix B The International System of Units (SI) A-9
Appendix C Conversion Factors A-11
Appendix D The Elements A-13
Appendix E Astrophysical Data A-16
Answers to Odd-Numbered Problems A-17
Credits C-1
Index I-1