Contents

Relative Velocity 68

Concepts and Calculations Problems 78

Concept Summary 72

Focus on Concepts 73

Additional Problems 77

Team Problems 79

Problems 74

1	Introduction and Mathematical	4 Forces and Newton's Laws of Motion
	Concepts 1	4.1 The Concepts of Force and Mass 80
4 4	The National Physics 1	4.2 Newton's First Law of Motion 81
1.1	The Nature of Physics 1	4.3 Newton's Second Law of Motion 83
1.2	Units 2 The Dele of Units in Drahlem Selving 3	4.4 The Vector Nature of Newton's Second Law of Motion
1.3	The Role of Units in Problem Solving 3	4.5 Newton's Third Law of Motion 86
1.4	Trigonometry 6 Scalars and Vectors 8	4.6 Types of Forces: An Overview 88
1.5	Vector Addition and Subtraction 10	4.7 The Gravitational Force 88
1.6	The Components of a Vector 12	4.8 The Normal Force 92
1.7		4.9 Static and Kinetic Frictional Forces 95
1.8	Addition of Vectors by Means of Components 15	4.10 The Tension Force 101
	cept Summary 19	4.11 Equilibrium Applications of Newton's Laws
	is on Concepts 19 Ilems 21	of Motion 102
	tional Problems 24	4.12 Nonequilibrium Applications of Newton's Laws
	tional Problems 24 tepts and Calculations Problems 25	of Motion 106
	n Problems 26	Concept Summary 111
Teall	Trioblems 20	Focus on Concepts 112
		Problems 114
2	Kinematics in One Dimension 27	Additional Problems 118
-		Concepts and Calculations Problems 119
2.1	Displacement 27	Team Problems 120
2.2	Speed and Velocity 28	
2.3	Acceleration 31	5 Dynamics of Uniform Circular
2.4	Equations of Kinematics for Constant	Motion 121
	Acceleration 34	
2.5	Applications of the Equations of Kinematics 37	5.1 Uniform Circular Motion 121
2.6	Freely Falling Bodies 41	5.2 Centripetal Acceleration 122
2.7	Graphical Analysis of Velocity and	5.3 Centripetal Force 125
	Acceleration 45	5.4 Banked Curves 129
	cept Summary 47	5.5 Satellites in Circular Orbits 130
	is on Concepts 48	5.6 Apparent Weightlessness and Artificial Gravity 133
	olems 49	5.7 *Vertical Circular Motion 136
	tional Problems 53	Concept Summary 137
	cepts and Calculations Problems 54	Focus on Concepts 138
Tean	n Problems 54	Problems 139
		Additional Problems 141
3	Kinematics in Two Dimensions 55	Concepts and Calculations Problems 142
		Team Problems 143
3.1	Displacement, Velocity, and Acceleration 55	
3.2	Equations of Kinematics in Two Dimensions 56	6 Work and Energy 144
3.3	Projectile Motion 60	

6.1

6.2

6.3

6.5

6.6

Theorem 161

Work Done by a Constant Force 144

Gravitational Potential Energy 153

The Work–Energy Theorem and Kinetic Energy 147

Conservative Versus Nonconservative Forces 155

The Conservation of Mechanical Energy 157

Nonconservative Forces and the Work-Energy

80

85

12.2 The Kelvin Temperature Scale 328

12.4 Linear Thermal Expansion 330

12.5 Volume Thermal Expansion 337

12.6 Heat and Internal Energy 339

12.3 Thermometers 329

Con Foci	Work Done by a Variable Force 164 cept Summary 166 us on Concepts 167 plems 168	Additional Problems 254 Concepts and Calculations Problems 255 Team Problems 256
Add Con	itional Problems 172 cepts and Calculations Problems 173 m Problems 174	10 Simple Harmonic Motion and Elasticity 257
Focu Prob Addi Con	Impulse and Momentum 175 The Impulse-Momentum Theorem 175 The Principle of Conservation of Linear Momentum 179 Collisions in One Dimension 184 Collisions in Two Dimensions 189 Center of Mass 189 cept Summary 192 us on Concepts 193 blems 194 itional Problems 197 cepts and Calculations Problems 198 m Problems 199	10.1 The Ideal Spring and Simple Harmonic Motion 257 10.2 Simple Harmonic Motion and the Reference Circle 261 10.3 Energy and Simple Harmonic Motion 267 10.4 The Pendulum 270 10.5 Damped Harmonic Motion 273 10.6 Driven Harmonic Motion and Resonance 274 10.7 Elastic Deformation 275 10.8 Stress, Strain, and Hooke's Law 279 Concept Summary 280 Focus on Concepts 281 Problems 282 Additional Problems 287 Concepts and Calculations Problems 288 Team Problems 288
8	Rotational Kinematics 200	11 Fluids 289
Focu Prob Addi Cond	Rotational Motion and Angular Displacement 200 Angular Velocity and Angular Acceleration 203 The Equations of Rotational Kinematics 205 Angular Variables and Tangential Variables 208 Centripetal Acceleration and Tangential Acceleration 210 Rolling Motion 213 *The Vector Nature of Angular Variables 214 cept Summary 215 us on Concepts 216 blems 216 ditional Problems 220 cepts and Calculations Problems 221 m Problems 222 Rotational Dynamics 223	11.1 Mass Density 289 11.2 Pressure 291 11.3 Pressure and Depth in a Static Fluid 293 11.4 Pressure Gauges 297 11.5 Pascal's Principle 298 11.6 Archimedes' Principle 300 11.7 Fluids in Motion 305 11.8 The Equation of Continuity 307 11.9 Bernoulli's Equation 309 11.10 Applications of Bernoulli's Equation 311 11.11 *Viscous Flow 314 Concept Summary 317 Focus on Concepts 318 Problems 319 Additional Problems 323 Concepts and Calculations Problems 324 Team Problems 325
9.1	The Action of Forces and Torques on Rigid Objects 223	12 Temperature and Heat 326
9.2	Rigid Objects in Equilibrium 226	12.1 Common Temperature Scales 326

Concept Summary 246

Focus on Concepts 247

Problems 248

6.7 Power 162

of Energy 164

Other Forms of Energy and the Conservation

6.8

9.3

9.6

Center of Gravity 231

9.5 Rotational Work and Energy 241

Angular Momentum 244

Fixed Axis 236

9.4 Newton's Second Law for Rotational Motion About a

12.7 Heat and Temperature Change: Specific Heat Capacity 340 12.8 Heat and Phase Change: Latent Heat 343 12.9 *Equilibrium Between Phases of Matter 347 12.10 *Humidity 350 Concept Summary 352 Focus on Concepts 352 Problems 353 Additional Problems 358	Concept Summary 425 Focus on Concepts 426 Problems 427 Additional Problems 431 Concepts and Calculations Problems 432 Team Problems 432 16 Waves and Sound 433
Concepts and Calculations Problems 358 Team Problems 359 13 The Transfer of Heat 360	 16.1 The Nature of Waves 433 16.2 Periodic Waves 435 16.3 The Speed of a Wave on a String 436 16.4 *The Mathematical Description of a Wave 439 16.5 The Nature of Sound 439
13.1 Convection 360 13.2 Conduction 363 13.3 Radiation 370 13.4 Applications 373 Concept Summary 375 Focus on Concepts 375 Problems 376 Additional Problems 378 Concepts and Calculations Problems 379 Team Problems 379	16.6 The Speed of Sound 442 16.7 Sound Intensity 446 16.8 Decibels 448 16.9 The Doppler Effect 450 16.10 Applications of Sound in Medicine 454 16.11 *The Sensitivity of the Human Ear 455 Concept Summary 456 Focus on Concepts 457 Problems 458 Additional Problems 463 Concepts and Calculations Problems 464
 The Ideal Gas Law and Kinetic Theory 380 Molecular Mass, the Mole, and Avogadro's Number 380 	Team Problems 464 17 The Principle of Linear Superposition and Interference Phenomena 465
14.2 The Ideal Gas Law 383 14.3 Kinetic Theory of Gases 388 14.4 *Diffusion 392 Concept Summary 395 Focus on Concepts 396 Problems 397 Additional Problems 399 Concepts and Calculations Problems 400 Team Problems 400	 17.1 The Principle of Linear Superposition 465 17.2 Constructive and Destructive Interference of Sound Waves 466 17.3 Diffraction 470 17.4 Beats 473 17.5 Transverse Standing Waves 474 17.6 Longitudinal Standing Waves 478 17.7 *Complex Sound Waves 481 Concept Summary 482
15.1 Thermodynamic Systems and Their Surroundings 401 15.2 The Zeroth Law of Thermodynamics 402 15.3 The First Law of Thermodynamics 402	Focus on Concepts 483 Problems 484 Additional Problems 487 Concepts and Calculations Problems 488 Team Problems 488
15.4 Thermal Processes 404 15.5 Thermal Processes Using an Ideal Gas 408 15.6 Specific Heat Capacities 411	18 Electric Forces and Electric Fields 48
 15.7 The Second Law of Thermodynamics 412 15.8 Heat Engines 413 15.9 Carnot's Principle and the Carnot Engine 414 15.10 Refrigerators, Air Conditioners, and Heat Pumps 417 15.11 Entropy 420 15.12 The Third Law of Thermodynamics 425 	 18.1 The Origin of Electricity 489 18.2 Charged Objects and the Electric Force 490 18.3 Conductors and Insulators 493 18.4 Charging by Contact and by Induction 493 18.5 Coulomb's Law 495 18.6 The Electric Field 500

Magnetic Forces and Magnetic

18.8 The Electric Field Inside a Conductor: Shielding 508	Fields 590
18.9 Gauss' Law 510	
18.10 *Copiers and Computer Printers 513	21.1 Magnetic Fields 590
Concept Summary 516	21.2 The Force That a Magnetic Field Exerts on a Moving
Focus on Concepts 516	Charge 592
Problems 517	21.3 The Motion of a Charged Particle in a Magnetic Field 595
Additional Problems 521	21.4 The Mass Spectrometer 599
Concepts and Calculations Problems 521	21.5 The Force on a Current in a Magnetic Field 600
Team Problems 522	21.6 The Torque on a Current-Carrying Coil 602
1.1	21.7 Magnetic Fields Produced by Currents 605
19 Electric Potential Energy and the	21.8 Ampère's Law 612
Electric Potential 523	21.9 Magnetic Materials 613
Licetife i oteritiat ()	Concept Summary 616
19.1 Potential Energy 523	Focus on Concepts 617
19.2 The Electric Potential Difference 524	Problems 618
19.2 The Electric Potential Difference Created by Point	Additional Problems 623
19.3 The Electric Potential Difference Created by Point	Concepts and Calculations Problems 624
Charges 530	Team Problems 624
19.4 Equipotential Surfaces and Their Relation to the	reality robtems
Electric Field 534	22 Electromagnetic Induction 625
19.5 Capacitors and Dielectrics 537	ZZ Electromagnetic madetion vzs
19.6 *Biomedical Applications of Electric Potential	22.1 Induced Emf and Induced Current 625
Differences 541	
Concept Summary 544	22.2 Motional Emf 627
Focus on Concepts 544	22.3 Magnetic Flux 631
Problems 546	22.4 Faraday's Law of Electromagnetic Induction 634
Additional Problems 548	22.5 Lenz's Law 637
Concepts and Calculations Problems 549	22.6 *Applications of Electromagnetic Induction to the
Team Problems 550	Reproduction of Sound 640
	22.7 The Electric Generator 641
20 Electric Circuits 551	22.8 Mutual Inductance and Self-Inductance 646
20 Liectife Circuits 332	22.9 Transformers 649
20.1 Electromotive Force and Current 551	Concept Summary 652
	Focus on Concepts 653
20.2 Ohm's Law 553	Problems 654
20.3 Resistance and Resistivity 554	Additional Problems 659
20.4 Electric Power 557	Concepts and Calculations Problems 659
20.5 Alternating Current 559	Team Problems 660
20.6 Series Wiring 562	
20.7 Parallel Wiring 565	23 Alternating Current Circuits 661
20.8 Circuits Wired Partially in Series and Partially in	According durient direction
Parallel 569	23.1 Capacitors and Capacitive Reactance 661
20.9 Internal Resistance 570	23.2 Inductors and Inductive Reactance 664
20.10 Kirchhoff's Rules 571	23.3 Circuits Containing Resistance, Capacitance, and
20.11 The Measurement of Current and Voltage 574	Inductance 665
20.12 Capacitors in Series and in Parallel 575	23.4 Resonance in Electric Circuits 670
20.13 <i>RC</i> Circuits 577	
20.14 Safety and the Physiological Effects of Current 579	23.5 Semiconductor Devices 672
Concept Summary 580	Concept Summary 678
Focus on Concepts 581	Focus on Concepts 679
Problems 582	Problems 680
Additional Problems 588	Additional Problems 681
Concepts and Calculations Problems 589	Concepts and Calculations Problems 682
Team Problems 589	Team Problems 683
Team Fronteins	

18.7 Electric Field Lines 505

Additional Problems 775
Concepts and Calculations Problems 775
Team Problems 776

27 Interference and the Wave Nature of Light 777

27	4 T	ho r	Dring	olai	ofI	inaar	Cuna	rposition	777
41.	1 1	ner	- mc	.ibie	OIL	ınear	Sube	LDOSILIOII	111

27.2 Young's Double-Slit Experiment 779

27.3 Thin-Film Interference 782

27.4 The Michelson Interferometer 786

27.5 Diffraction 787

27.6 Resolving Power 791

27.7 The Diffraction Grating 796

27.8 *Compact Discs, Digital Video Discs, and the Use of Interference 798

27.9 X-Ray Diffraction 799

Concept Summary 801

Focus on Concepts 802

Problems 803

Additional Problems 805

Concepts and Calculations Problems 806

Team Problems 807

28 Special Relativity 808

28.1	Events and	Inertial	Reference Frames	808
------	-------------------	----------	------------------	-----

28.2 The Postulates of Special Relativity 809

28.3 The Relativity of Time: Time Dilation 811

28.4 The Relativity of Length: Length Contraction 815

28.5 Relativistic Momentum 817

28.6 The Equivalence of Mass and Energy 819

28.7 The Relativistic Addition of Velocities 824

Concept Summary 827

Focus on Concepts 827

Problems 828

Additional Problems 830

Concepts and Calculations Problems 831

Team Problems 831

29 Particles and Waves 832

29.1 The Wave-Particle Duality 832

29.2 Blackbody Radiation and Planck's Constant 833

29.3 Photons and the Photoelectric Effect 834

29.4 The Momentum of a Photon and the Compton Effect 840

29.5 The De Broglie Wavelength and the Wave Nature of Matter **843**

29.6 The Heisenberg Uncertainty Principle 845

Concept Summary 849

Focus on Concepts 849

Problems 850

Additional Problems 852 Concepts and Calculations Problems 852 Team Problems 852

30 The Nature of the Atom 853

- 30.1 Rutherford Scattering and the Nuclear Atom 853
- 30.2 Line Spectra 855
- 30.3 The Bohr Model of the Hydrogen Atom 857
- 30.4 De Broglie's Explanation of Bohr's Assumption About Angular Momentum 861
- 30.5 The Quantum Mechanical Picture of the Hydrogen Atom 862
- 30.6 The Pauli Exclusion Principle and the Periodic Table of the Elements 866
- 30.7 X-Rays 868
- 30.8 The Laser 872
- 30.9 *Medical Applications of the Laser 874
- 30.10 *Holography 876

Concept Summary 878

Focus on Concepts 879

Problems 880

Additional Problems 883

Concepts and Calculations Problems 883

Team Problems 883

31 Nuclear Physics and Radioactivity 885

- 31.1 Nuclear Structure 885
- 31.2 The Strong Nuclear Force and the Stability of the Nucleus 887
- 31.3 The Mass Defect of the Nucleus and Nuclear Binding Energy 888
- 31.4 Radioactivity 890
- 31.5 The Neutrino 896
- 31.6 Radioactive Decay and Activity 897
- 31.7 Radioactive Dating 900
- 31.8 Radioactive Decay Series 903
- 31.9 Radiation Detectors 904

Concept Summary 906
Focus on Concepts 907
Problems 908
Additional Problems 910
Concepts and Calculations Problems 910
Team Problems 910

32 Ionizing Radiation, Nuclear Energy, and Elementary Particles 911

- 32.1 Biological Effects of Ionizing Radiation 911
- 32.2 Induced Nuclear Reactions 915
- 32.3 Nuclear Fission 916
- 32.4 Nuclear Reactors 919
- 32.5 Nuclear Fusion 920
- 32.6 Elementary Particles 922
- 32.7 Cosmology 928

Concept Summary 931

Focus on Concepts 932

Problems 932

Additional Problems 934

Concepts and Calculations Problems 935

Team Problems 935

Appendixes A-1

APPENDIX A Powers of Ten and Scientific Notation A-1

APPENDIX B Significant Figures A-1

APPENDIX C Algebra A-2

APPENDIX D Exponents and Logarithms A-3

APPENDIX E Geometry and Trigonometry A-4

APPENDIX F Selected Isotopes A-5

ANSWERS TO CHECK YOUR UNDERSTANDING A-10

ANSWERS TO ODD-NUMBERED PROBLEMS A-18

INDEX I-1

Note: Chapter sections marked with an asterisk (*) can be omitted with little impact to the overall development of the material.