

GLOBAL
EDITION



University Physics

with Modern Physics

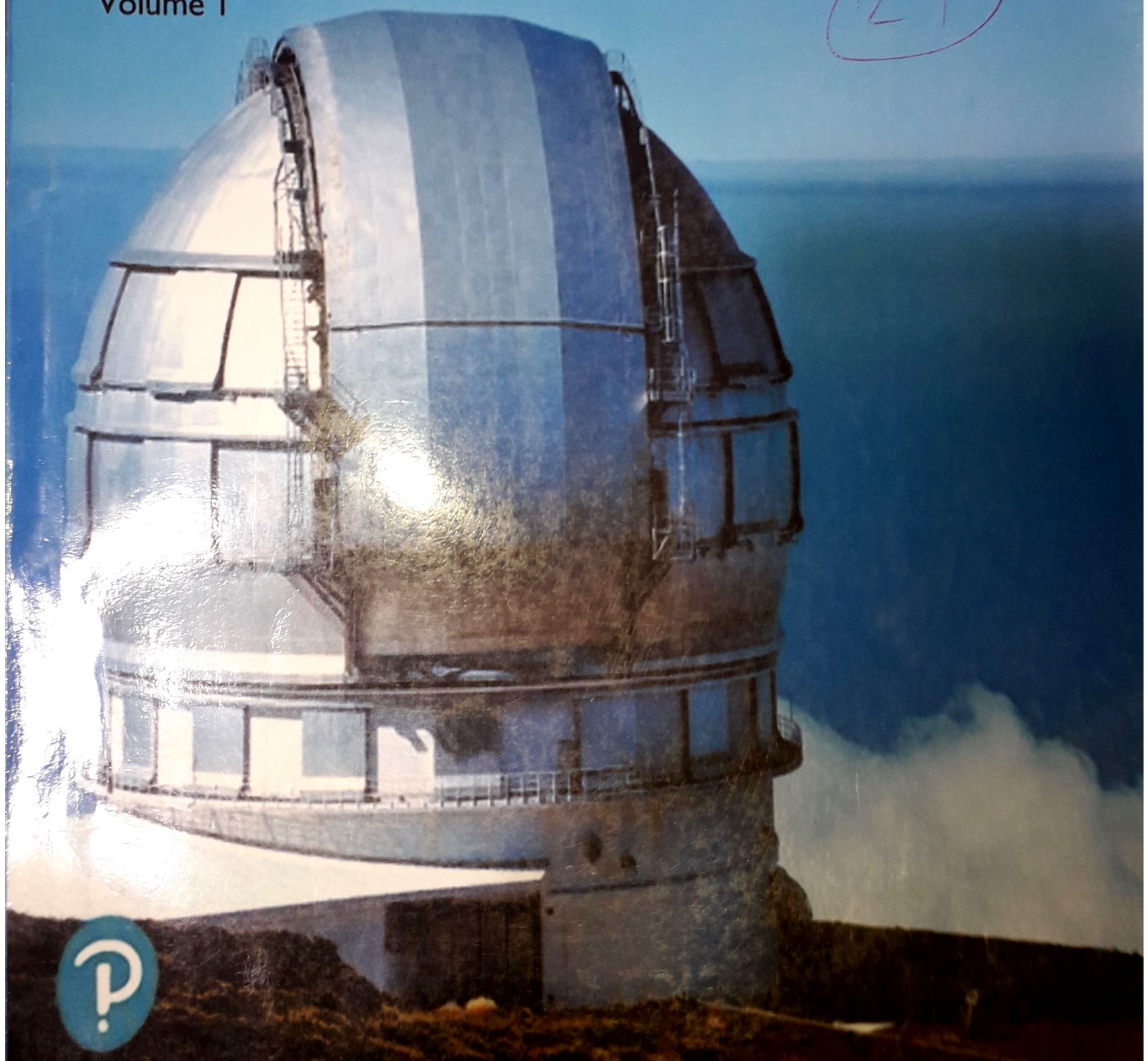
Fifteenth Edition in SI Units

Hugh D. Young • Roger A. Freedman

Volume I

14682

213



DETAILED CONTENTS

MECHANICS

1	UNITS, PHYSICAL QUANTITIES, AND VECTORS	29
1.1	The Nature of Physics	29
1.2	Solving Physics Problems	30
1.3	Standards and Units	31
1.4	Using and Converting Units	34
1.5	Uncertainty and Significant Figures	36
1.6	Estimates and Orders of Magnitude	38
1.7	Vectors and Vector Addition	38
1.8	Components of Vectors	42
1.9	Unit Vectors	46
1.10	Products of Vectors	47
	Summary	53
	Guided Practice	54
	Questions/Exercises/Problems	55

2	MOTION ALONG A STRAIGHT LINE	62
2.1	Displacement, Time, and Average Velocity	62
2.2	Instantaneous Velocity	65
2.3	Average and Instantaneous Acceleration	68
2.4	Motion with Constant Acceleration	72
2.5	Freely Falling Objects	78
2.6	Velocity and Position by Integration	81
	Summary	84
	Guided Practice	85
	Questions/Exercises/Problems	86

3	MOTION IN TWO OR THREE DIMENSIONS	94
3.1	Position and Velocity Vectors	94
3.2	The Acceleration Vector	97
3.3	Projectile Motion	102
3.4	Motion in a Circle	109
3.5	Relative Velocity	112
	Summary	118
	Guided Practice	119
	Questions/Exercises/Problems	120

4	NEWTON'S LAWS OF MOTION	128
4.1	Force and Interactions	128
4.2	Newton's First Law	131
4.3	Newton's Second Law	135
4.4	Mass and Weight	140
4.5	Newton's Third Law	143



4.6	Free-Body Diagrams	
	Summary	
	Guided Practice	
	Questions/Exercises/Problems	

5 APPLYING NEWTON'S LAWS

5.1	Using Newton's First Law: Particles in Equilibrium	
5.2	Using Newton's Second Law: Dynamics of Particles	
5.3	Friction Forces	
5.4	Dynamics of Circular Motion	
5.5	The Fundamental Forces of Nature	
	Summary	
	Guided Practice	
	Questions/Exercises/Problems	

6 WORK AND KINETIC ENERGY

6.1	Work	
6.2	Kinetic Energy and the Work-Energy Theorem	
6.3	Work and Energy with Varying Forces	
6.4	Power	
	Summary	
	Guided Practice	
	Questions/Exercises/Problems	

7 POTENTIAL ENERGY AND ENERGY CONSERVATION

7.1	Gravitational Potential Energy	
7.2	Elastic Potential Energy	
7.3	Conservative and Nonconservative Forces	
7.4	Force and Potential Energy	

7.5	Energy Diagrams	250
	Summary	252
	Guided Practice	253
	Questions/Exercises/Problems	254

8 MOMENTUM, IMPULSE, AND COLLISIONS 263

8.1	Momentum and Impulse	263
8.2	Conservation of Momentum	269
8.3	Momentum Conservation and Collisions	273
8.4	Elastic Collisions	277
8.5	Center of Mass	281
8.6	Rocket Propulsion	284
	Summary	288
	Guided Practice	289
	Questions/Exercises/Problems	290



9 ROTATION OF RIGID BODIES 300

9.1	Angular Velocity and Acceleration	300
9.2	Rotation with Constant Angular Acceleration	305
9.3	Relating Linear and Angular Kinematics	307
9.4	Energy in Rotational Motion	310
9.5	Parallel-Axis Theorem	315
9.6	Moment-of-Inertia Calculations	317
	Summary	319
	Guided Practice	320
	Questions/Exercises/Problems	321

10 DYNAMICS OF ROTATIONAL MOTION 330

10.1	Torque	330
10.2	Torque and Angular Acceleration for a Rigid Body	333
10.3	Rigid-Body Rotation About a Moving Axis	336
10.4	Work and Power in Rotational Motion	342
10.5	Angular Momentum	344
10.6	Conservation of Angular Momentum	347

10.7	Gyroscopes and Precession	350
	Summary	353
	Guided Practice	354
	Questions/Exercises/Problems	355

11 EQUILIBRIUM AND ELASTICITY 365

11.1	Conditions for Equilibrium	365
11.2	Center of Gravity	366
11.3	Solving Rigid-Body Equilibrium Problems	369
11.4	Stress, Strain, and Elastic Moduli	373
11.5	Elasticity and Plasticity	379
	Summary	381
	Guided Practice	382
	Questions/Exercises/Problems	383

12 FLUID MECHANICS 394

12.1	Gases, Liquids, and Density	394
12.2	Pressure in a Fluid	396
12.3	Buoyancy	401
12.4	Fluid Flow	404
12.5	Bernoulli's Equation	406
12.6	Viscosity and Turbulence	410
	Summary	413
	Guided Practice	414
	Questions/Exercises/Problems	415

13 GRAVITATION 423

13.1	Newton's Law of Gravitation	423
13.2	Weight	427
13.3	Gravitational Potential Energy	430
13.4	The Motion of Satellites	432
13.5	Kepler's Laws and the Motion of Planets	435
13.6	Spherical Mass Distributions	439
13.7	Apparent Weight and the Earth's Rotation	442
13.8	Black Holes	443
	Summary	447
	Guided Practice	448
	Questions/Exercises/Problems	449

14 PERIODIC MOTION 457

14.1	Describing Oscillation	457
14.2	Simple Harmonic Motion	459
14.3	Energy in Simple Harmonic Motion	466
14.4	Applications of Simple Harmonic Motion	470
14.5	The Simple Pendulum	474
14.6	The Physical Pendulum	475
14.7	Damped Oscillations	477
14.8	Forced Oscillations and Resonance	479
	Summary	481
	Guided Practice	483
	Questions/Exercises/Problems	484

WAVES/ACOUSTICS

15	MECHANICAL WAVES	492
15.1	Types of Mechanical Waves	492
15.2	Periodic Waves	494
15.3	Mathematical Description of a Wave	497
15.4	Speed of a Transverse Wave	502
15.5	Energy in Wave Motion	506
15.6	Wave Interference, Boundary Conditions, and Superposition	509
15.7	Standing Waves on a String	511
15.8	Normal Modes of a String	514
	Summary	519
	Guided Practice	520
	Questions/Exercises/Problems	521
16	SOUND AND HEARING	529
16.1	Sound Waves	529
16.2	Speed of Sound Waves	534
16.3	Sound Intensity	538
16.4	Standing Sound Waves and Normal Modes	542
16.5	Resonance and Sound	546
16.6	Interference of Waves	548
16.7	Beats	550
16.8	The Doppler Effect	552
16.9	Shock Waves	557
	Summary	559
	Guided Practice	561
	Questions/Exercises/Problems	562

THERMODYNAMICS

17	TEMPERATURE AND HEAT	569
17.1	Temperature and Thermal Equilibrium	569
17.2	Thermometers and Temperature Scales	571
17.3	Thermal Expansion	574
17.4	Quantity of Heat	580
17.5	Calorimetry and Phase Changes	583
17.6	Mechanisms of Heat Transfer	589
	Summary	596
	Guided Practice	597
	Questions/Exercises/Problems	598
18	THERMAL PROPERTIES OF MATTER	607
18.1	Equations of State	607
18.2	Molecular Properties of Matter	613
18.3	Kinetic-Molecular Model of an Ideal Gas	616
18.4	Heat Capacities	622
18.5	Molecular Speeds	625

18.6	Phases of Matter
	Summary
	Guided Practice
	Questions/Exercises/Problems

19 THE FIRST LAW OF THERMODYNAMICS

19.1	Thermodynamic Systems
19.2	Work Done During Volume Changes
19.3	Paths Between Thermodynamic States
19.4	Internal Energy and the First Law of Thermodynamics
19.5	Kinds of Thermodynamic Processes
19.6	Internal Energy of an Ideal Gas
19.7	Heat Capacities of an Ideal Gas
19.8	Adiabatic Processes for an Ideal Gas
	Summary
	Guided Practice
	Questions/Exercises/Problems

**20 THE SECOND LAW OF THERMODYNAMICS**

20.1	Directions of Thermodynamic Processes
20.2	Heat Engines
20.3	Internal-Combustion Engines
20.4	Refrigerators
20.5	The Second Law of Thermodynamics
20.6	The Carnot Cycle
20.7	Entropy
20.8	Microscopic Interpretation of Entropy
	Summary
	Guided Practice
	Questions/Exercises/Problems

ELECTROMAGNETISM**21 ELECTRIC CHARGE AND ELECTRIC FIELD 706**

21.1	Electric Charge	707
21.2	Conductors, Insulators, and Induced Charges	710
21.3	Coulomb's Law	713
21.4	Electric Field and Electric Forces	718
21.5	Electric-Field Calculations	722
21.6	Electric Field Lines	728
21.7	Electric Dipoles	729
	Summary	734
	Guided Practice	735
	Questions/Exercises/Problems	736

22 GAUSS'S LAW 746

22.1	Charge and Electric Flux	746
22.2	Calculating Electric Flux	749
22.3	Gauss's Law	753
22.4	Applications of Gauss's Law	757
22.5	Charges on Conductors	762
	Summary	766
	Guided Practice	767
	Questions/Exercises/Problems	768

23 ELECTRIC POTENTIAL 775

23.1	Electric Potential Energy	775
23.2	Electric Potential	782
23.3	Calculating Electric Potential	788
23.4	Equipotential Surfaces	792
23.5	Potential Gradient	795
	Summary	798
	Guided Practice	799
	Questions/Exercises/Problems	800

24 CAPACITANCE AND DIELECTRICS 809

24.1	Capacitors and Capacitance	810
24.2	Capacitors in Series and Parallel	814
24.3	Energy Storage in Capacitors and Electric-Field Energy	818
24.4	Dielectrics	821
24.5	Molecular Model of Induced Charge	827
24.6	Gauss's Law in Dielectrics	829
	Summary	830
	Guided Practice	831
	Questions/Exercises/Problems	832

25 CURRENT, RESISTANCE, AND ELECTROMOTIVE FORCE 840

25.1	Current	841
25.2	Resistivity	844
25.3	Resistance	847

25.4	Electromotive Force and Circuits	850
25.5	Energy and Power in Electric Circuits	856
25.6	Theory of Metallic Conduction	860
	Summary	863
	Guided Practice	864
	Questions/Exercises/Problems	865

26 DIRECT-CURRENT CIRCUITS 872

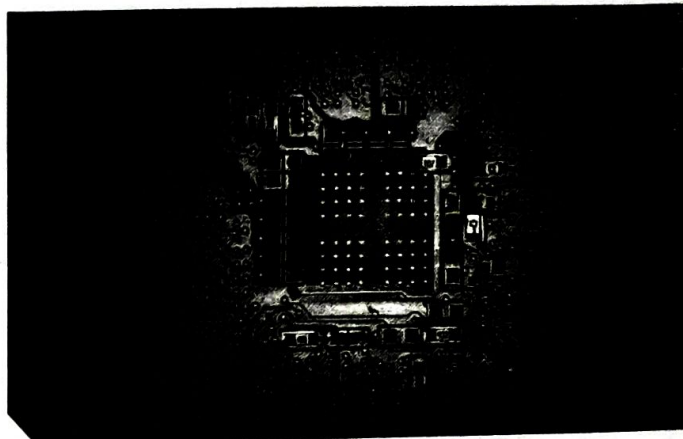
26.1	Resistors in Series and Parallel	872
26.2	Kirchhoff's Rules	877
26.3	Electrical Measuring Instruments	882
26.4	R-C Circuits	886
26.5	Power Distribution Systems	891
	Summary	895
	Guided Practice	896
	Questions/Exercises/Problems	897

27 MAGNETIC FIELD AND MAGNETIC FORCES 906

27.1	Magnetism	906
27.2	Magnetic Field	908
27.3	Magnetic Field Lines and Magnetic Flux	912
27.4	Motion of Charged Particles in a Magnetic Field	916
27.5	Applications of Motion of Charged Particles	919
27.6	Magnetic Force on a Current-Carrying Conductor	921
27.7	Force and Torque on a Current Loop	925
27.8	The Direct-Current Motor	930
27.9	The Hall Effect	932
	Summary	934
	Guided Practice	935
	Questions/Exercises/Problems	936

28 SOURCES OF MAGNETIC FIELD 946

28.1	Magnetic Field of a Moving Charge	946
28.2	Magnetic Field of a Current Element	949



28.3	Magnetic Field of a Straight Current-Carrying Conductor	951
28.4	Force Between Parallel Conductors	954
28.5	Magnetic Field of a Circular Current Loop	955
28.6	Ampere's Law	958
28.7	Applications of Ampere's Law	961
28.8	Magnetic Materials	965
	Summary	970
	Guided Practice	971
	Questions/Exercises/Problems	972

29 ELECTROMAGNETIC INDUCTION 981

29.1	Induction Experiments	982
29.2	Faraday's Law	983
29.3	Lenz's Law	990
29.4	Motional EMF	993
29.5	Induced Electric Fields	995
29.6	Eddy Currents	997
29.7	Displacement Current and Maxwell's Equations	998
29.8	Superconductivity	1003
	Summary	1005
	Guided Practice	1006
	Questions/Exercises/Problems	1007

30 INDUCTANCE 1016

30.1	Mutual Inductance	1016
30.2	Self-Inductance and Inductors	1020
30.3	Magnetic-Field Energy	1023
30.4	The R - L Circuit	1026
30.5	The L - C Circuit	1030
30.6	The L - R - C Series Circuit	1035
	Summary	1037
	Guided Practice	1038
	Questions/Exercises/Problems	1039

31 ALTERNATING CURRENT 1046

31.1	Phasors and Alternating Currents	1046
31.2	Resistance and Reactance	1050
31.3	The L - R - C Series Circuit	1055
31.4	Power in Alternating-Current Circuits	1059
31.5	Resonance in Alternating-Current Circuits	1062
31.6	Transformers	1064
	Summary	1068
	Guided Practice	1069
	Questions/Exercises/Problems	1070

32 ELECTROMAGNETIC WAVES 1076

32.1	Maxwell's Equations and Electromagnetic Waves	1076
32.2	Plane Electromagnetic Waves and the Speed of Light	1080
32.3	Sinusoidal Electromagnetic Waves	1085

32.4	Energy and Momentum in Electromagnetic Waves
32.5	Standing Electromagnetic Waves
	Summary
	Guided Practice
	Questions/Exercises/Problems

OPTICS

33 THE NATURE AND PROPAGATION OF LIGHT

33.1	The Nature of Light
33.2	Reflection and Refraction
33.3	Total Internal Reflection
33.4	Dispersion
33.5	Polarization
33.6	Scattering of Light
33.7	Huygens's Principle
	Summary
	Guided Practice
	Questions/Exercises/Problems

34 GEOMETRIC OPTICS

34.1	Reflection and Refraction at a Plane Surface
34.2	Reflection at a Spherical Surface
34.3	Refraction at a Spherical Surface
34.4	Thin Lenses
34.5	Cameras
34.6	The Eye
34.7	The Magnifier
34.8	Microscopes and Telescopes
	Summary
	Guided Practice
	Questions/Exercises/Problems

35 INTERFERENCE

35.1	Interference and Coherent Sources
35.2	Two-Source Interference of Light



5.3	Intensity in Interference Patterns	1194
5.4	Interference in Thin Films	1198
5.5	The Michelson Interferometer	1203
	Summary	1205
	Guided Practice	1206
	Questions/Exercises/Problems	1207

36 DIFFRACTION 1213

36.1	Fresnel and Fraunhofer Diffraction	1213
36.2	Diffraction from a Single Slit	1215
36.3	Intensity in the Single-Slit Pattern	1218
36.4	Multiple Slits	1222
36.5	The Diffraction Grating	1224
36.6	X-Ray Diffraction	1228
36.7	Circular Apertures and Resolving Power	1231
36.8	Holography	1234
	Summary	1236
	Guided Practice	1236
	Questions/Exercises/Problems	1237

MODERN PHYSICS

37 RELATIVITY 1245

37.1	Invariance of Physical Laws	1245
37.2	Relativity of Simultaneity	1248
37.3	Relativity of Time Intervals	1250
37.4	Relativity of Length	1255
37.5	The Lorentz Transformations	1259
37.6	The Doppler Effect for Electromagnetic Waves	1263
37.7	Relativistic Momentum	1265
37.8	Relativistic Work and Energy	1267
37.9	Newtonian Mechanics and Relativity	1271
	Summary	1272
	Guided Practice	1273
	Questions/Exercises/Problems	1274

38 PHOTONS: LIGHT WAVES BEHAVING AS PARTICLES 1281

38.1	Light Absorbed as Photons: The Photoelectric Effect	1281
38.2	Light Emitted as Photons: X-Ray Production	1287
38.3	Light Scattered as Photons: Compton Scattering and Pair Production	1290
38.4	Wave-Particle Duality, Probability, and Uncertainty	1293
	Summary	1300
	Guided Practice	1301
	Questions/Exercises/Problems	1302

39 PARTICLES BEHAVING AS WAVES 1307

39.1	Electron Waves	1307
39.2	The Nuclear Atom and Atomic Spectra	1313



39.3	Energy Levels and the Bohr Model of the Atom	1318
39.4	The Laser	1328
39.5	Continuous Spectra	1331
39.6	The Uncertainty Principle Revisited	1336
	Summary	1339
	Guided Practice	1340
	Questions/Exercises/Problems	1341

40 QUANTUM MECHANICS I: WAVE FUNCTIONS 1349

40.1	Wave Functions and the One-Dimensional Schrödinger Equation	1349
40.2	Particle in a Box	1359
40.3	Potential Wells	1364
40.4	Potential Barriers and Tunneling	1368
40.5	The Harmonic Oscillator	1371
40.6	Measurement in Quantum Mechanics	1375
	Summary	1378
	Guided Practice	1379
	Questions/Exercises/Problems	1381

41 QUANTUM MECHANICS II: ATOMIC STRUCTURE 1388

41.1	The Schrödinger Equation in Three Dimensions	1388
41.2	Particle in a Three-Dimensional Box	1390
41.3	The Hydrogen Atom	1395
41.4	The Zeeman Effect	1403
41.5	Electron Spin	1406
41.6	Many-Electron Atoms and the Exclusion Principle	1413
41.7	X-Ray Spectra	1420
41.8	Quantum Entanglement	1423
	Summary	1427
	Guided Practice	1428
	Questions/Exercises/Problems	1429

14602

**42 MOLECULES AND
CONDENSED MATTER**

1436

42.1	Types of Molecular Bonds	1436
42.2	Molecular Spectra	1439
42.3	Structure of Solids	1443
42.4	Energy Bands	1446
42.5	Free-Electron Model of Metals	1449
42.6	Semiconductors	1453
42.7	Semiconductor Devices	1456
42.8	Superconductivity	1461
	Summary	1461
	Guided Practice	1462
	Questions/Exercises/Problems	1463

43 NUCLEAR PHYSICS

1470

43.1	Properties of Nuclei	1470
43.2	Nuclear Binding and Nuclear Structure	1475
43.3	Nuclear Stability and Radioactivity	1480
43.4	Activities and Half-Lives	1487
43.5	Biological Effects of Radiation	1491
43.6	Nuclear Reactions	1493
43.7	Nuclear Fission	1496
43.8	Nuclear Fusion	1500
	Summary	1503
	Guided Practice	1504
	Questions/Exercises/Problems	1505

**44 PARTICLE PHYSICS
AND COSMOLOGY**

44.1	Fundamental Particles—A History
44.2	Particle Accelerators and Detectors
44.3	Particles and Interactions
44.4	Quarks and Gluons
44.5	The Standard Model and Beyond
44.6	The Expanding Universe
44.7	The Beginning of Time
	Summary
	Guided Practice
	Questions/Exercises/Problems

APPENDICES

A	The International System of Units
B	Unit Conversion Factors
C	The British System of Units
D	Useful Mathematical Relations
E	The Greek Alphabet
F	Periodic Table of the Elements
G	Numerical Constants
	Answers to Odd-Numbered Problems
	Credits
	Index