

HALLIDAY & RESNICK

Fundamentals of

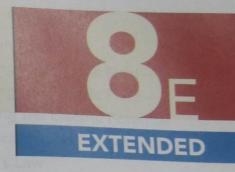
PHYSICS

Eighth Edition EXTENDED Jearl Walker

530 IXAL 2008

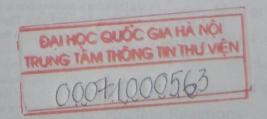
HALLIDAY / RESNICK

Fundamentals of Physics



Jearl Walker

Cleveland State University



John Wiley & Sons, Inc.



Brief Contents

PART 1		PART 3	
Chapter 1	Measuring	Chapter 21	Coulomb's Law
Chapter 2	Straight Line Motion	Chapter 22	Finding the Electric Field—I
Chapter 3	Vector Quantities	Chapter 23	Finding the Electric Field—II
Chapter 4		Chapter 24	Finding the Electric Potential
	Motion	Chapter 25	Capacitors and Capacitance
Chapter 5		Chapter 26	Ohm's Law
Chapter 6		Chapter 27	Circuit Theory
	Force	Chapter 28	Magnetic Force
	Work-Kinetic Energy Theorem	Chapter 29	Current-Produced Magnetic
Chapter 8			Fields
Chapter 9			Inductance
	Rotational Motion—I		Alternating Fields and Current
Chapter 11	Rotational Motion—II	Chapter 32	Maxwell's Equations, Models of
PART 2			Magnetism
Chapter 12	Equilibrium, Indeterminate	PART 4	
	Structures	Chapter 33	Nature of Electromagnetic Wave
Chapter 13	Newtonian Gravitation	Chapter 34	Geometric Optics
Chapter 14	Fluid Statics and Dynamics		Optical Interference
Chapter 15	Simple Harmonic Motion		Optical Diffraction
Chapter 16	Transverse Waves		Special Relativity
Chapter 17	Longitudinal Waves		,
Chapter 18	First Law of Thermodynamics	PART 5	
	Kinetic Theory	Chapter 38	Light Quanta, Matter Waves
	Second Law of Thermodynamics	Chapter 39	Matter-Waves Traps
	and an inclinedynamics	Chapter 40	Atoms, X Rays, and Lasers
		Chapter 41	Electrical Properties of Materials
		Chapter 42	Nuclear Reactions
		Chapter 43	Energy from Nuclear Reactions
		Chapter 44	- 1 15 11

Appendices / Answers to Checkpoints and Odd-Numbered Questions and Problems / Index

Cosmology

Contents

Measuring 1

How can the ground become fluid and sallow up buildings?

- 1-1 What Is Physics? 2
- 1-2 Measuring Things 2
- 1-3 The International System of Units 2
- 1-4 Changing Units 3
- 1-5 Length 4
- 1-6 Time 5
- 1-7 Mass 7

Review & Summary 8

Problems 8

Straight Line Motion 13

How can a woodpecker survive the severe impacts of its beak on a tree?

- 2-1 What Is Physics? 14
- 2-2 Motion 14
- 2-3 Position and Displacement 14
- 2-4 Average Velocity and Average Speed 15
- 2-5 Instantaneous Velocity and Speed 17
- 2-6 Acceleration 19
- 2-7 Constant Acceleration: A Special Case 21
- 2-8 Another Look at Constant Acceleration 24
- 2-9 Free-Fall Acceleration 24
- 2-10 Graphical Integration in Motion Analysis 27

Review & Summary 28

Questions 29 / Problems 30

3 Vector Quantities 38

How does an ant know the way home with no guiding clues on the desert plains?

- 3-1 What Is Physics? 39
- 3-2 Vectors and Scalars 39
- 3-3 Adding Vectors Geometrically 39
- 3-4 Components of Vectors 40
- 3-5 Unit Vectors 44
- 3-6 Adding Vectors by Components 45
- 3-7 Vectors and the Laws of Physics 48
- 3-8 Multiplying Vectors 48

Review & Summary 52

Questions 52 / Problems 53

Two- and Three-Dimensional Motion 58

How does an outfielder know where to run to catch a high fly ball?

- 4-1 What Is Physics? 59
- 4-2 Position and Displacement 59
- 4-3 Average Velocity and Instantaneous Velocity 61
- **4-4** Average Acceleration and Instantaneous Acceleration 63
- 4-5 Projectile Motion 65
- 4-6 Projectile Motion Analyzed 66
- 4-7 Uniform Circular Motion 70
- 4-8 Relative Motion in One Dimension 72
- 4-9 Relative Motion in Two Dimensions 73

Review & Summary 75

Questions 76 / Problems 77

Newton's Laws of Motion 87

What is the fear factor in riding the last car on a roller coaster?

- 5-1 What Is Physics? 88
- 5-2 Newtonian Mechanics 88
- 5-3 Newton's First Law 88
- 5-4 Force 89
- **5-5** Mass 90
- 5-6 Newton's Second Law 91
- 5-7 Some Particular Forces 94
- 5-8 Newton's Third Law 99
- 5-9 Applying Newton's Laws 99

Review & Summary 105

Questions 106 / Problems 108

Friction, Drag, and Centripetal Force

How did the ancient Egyptians move the huge blocks into place to build the Great Pyramid?

- 6-1 What Is Physics? 117
- 6-2 Friction 117
- 6-3 Properties of Friction 118
- 6-4 The Drag Force and Terminal Speed 122
- 6-5 Uniform Circular Motion 124

Review & Summary 129

Questions 130 / Problems 131

Work-Kinetic Energy Theorem 140

What property of a funny car determines the winning time An a chap race?

- What is Physics? 141
- 7.2 What is Energy? 141
- 7.3 Kinetic Energy 141
- Work 142
- 7.5 Work and Kinetic Energy 143
- 7.4 Work Done by the Gravitational Force 146
- 7.7 Work Done by a Spring Force 149
- Work Done by a General Variable Force 152
- Power 155

Review & Summary 157

Questions 158 / Problems 159

Conservation of Energy 166

Why can a large landslide move almost 30 times as far across a valley as a small landslide?

- What Is Physics? 167
- 8-2 Work and Potential Energy 167
- 8-3
- 8-4 Determining Potential Energy Values 170
- Conservation of Mechanical Energy 173
- Reading a Potential Energy Curve 175
- Work Done on a System by an External Force 179
- Conservation of Energy 182

Review & Summary 186

Questions 187 / Problems 189

Center of Mass and Momentum 201

How can a male bighorn sheep survive the severe head collision with which it gains dominance?

- 9-1 What Is Physics? 202
- 9-2 The Center of Mass 202
- 9-3 Newton's Second Law for a System of Particles 206
- 9.4 Linear Momentum 209
- 9.5 The Linear Momentum of a System of Particles 210
- 9-6 Collision and Impulse 210
- 9-7 Conservation of Linear Momentum 214
- 9-8 Momentum and Kinetic Energy in Collisions 217
- 9.9 Inelastic Collisions in One Dimension 218
- 9-10 Elastic Collisions in One Dimension 221
- 9-11 Collisions in Two Dimensions 224
- 9-12 Systems with Varying Mass: A Rocket 224.

Review & Summary 226

Questions 228 / Problems 229

Rotational Motion—1 241

How can a small snapping shrimp snap its claw so firmly that the sound stuns its prey?

- 10-1 What Is Physics? 242
- The Rotational Variables 242 10.2
- Are Angular Quantities Vectors? 246 10-3
- Rotation with Constant Angular Acceleration 247 10.4
- Relating the Linear and Angular Variables 249 10-5
- Kinetic Energy of Rotation 252 10.6
- Calculating the Rotational Inertia 253 10.7
- 10-8 Torque 256
- 10-9 Newton's Second Law for Rotation 257
- 10-10 Work and Rotational Kinetic Energy 260

Review & Summary 263

Questions 265 / Problems 266

Rotational Motion—II 275

What is the magic behind the onset of a ballet dancer's midair rotation during a tour jeté?

- What Is Physics? 276 11-1
- Rolling as Translation and Rotation Combined 276 11-2
- 11-3 The Kinetic Energy of Rolling 277
- The Forces of Rolling 278 77-4
- 11-5 The Yo-Yo 281
- 11-6 Torque Revisited 281
- 11-7 Angular Momentum 283
- 11-8 Newton's Second Law in Angular Form 285
- 11-9 The Angular Momentum of a System of Particles 287
- 11-10 The Angular Momentum of a Rigid Body Rotating About a Fixed Axis 287
- 11-11 Conservation of Angular Momentum 290
- Precession of a Gyroscope 293

Review & Summary 295

Questions 296 / Problems 297

Equilibrium, Indeterminate Structures 305

Why is even the slight tilt of the leaning tower in Pisa dangerous?

- 12-1 What Is Physics? 306
- 12-2 Equilibrium 306
- 12-3 The Requirements of Equilibrium 307
- 12-4 The Center of Gravity 308
- 12-5 Some Examples of Static Equilibrium 310
- 12-6 Indeterminate Structures 314
- 12-7 Elasticity 315

Review & Summary 319

Questions 319 / Problems 321

Newtonian Gravitation 330

What "monster" lurks at the center of our Milky Way Galaxy?

- 13-1 What Is Physics? 331
- Newton's Law of Gravitation 331 13-2
- Gravitation and the Principle of Superposition 333 13-3
- Gravitation Near Earth's Surface 335 13-4
- Gravitation Inside Earth 337 13-5
- Gravitation Potential Energy 338 13-6
- Planets and Satellites: Kepler's Laws 342 13-7
- Satellites: Orbits and Energy 345 13-8
- Einstein and Gravitation 347 13-9

Review & Summary 349

Questions 350 / Problems 351

Fluid Statics and Dynamics 359

How does a surfer surf?

- What Is Physics? 360 14-1
- 14-2 What Is a Fluid? 360
- 14-3 Density and Pressure 360
- 14-4 Fluids at Rest 362
- Measuring Pressure 365 14-5
- 14-6 Pascal's Principle 366
- 14-7 Archimedes' Principle 367
- 14-8 Ideal Fluids in Motion 370
- 14-9 The Equation of Continuity 371
- 14-10 Bernoulli's Equation 373

Review & Summary 377

Questions 378 / Problems 379

Simple Harmonic Motion 386

How can you stop the natural but annoying oscillations of a tall building in a wind?

- 15-1 What Is Physics? 387
- 15-2 Simple Harmonic Motion 387
- 15-3 The Force Law for Simple Harmonic Motion 390
- 15-4 Energy in Simple Harmonic Motion 392
- 15-5 An Angular Simple Harmonic Oscillator 394
- 15-6 Pendulums 395
- 15-7 Simple Harmonic Motion and Uniform Circular Motion 399
- 15-8 Damped Simple Harmonic Motion 400
- 15-9 Forced Oscillations and Resonance 402

Review & Summary 403

Questions 403 / Problems 405

Transverse Waves 413

What causes the sometimes dangerous oscillations of footbridges and mosh pits?

- What Is Physics? 414 16-1
- 16-2 Types of Waves 414
- 16-3 Transverse and Longitudinal Waves 414
- 16-4 Wavelength and Frequency 416
- 16-5 The Speed of a Traveling Wave 418
- 16-6 Wave Speed on a Stretched String 412
- 16-7 Energy and Power of a Wave Traveling Along a String 423
- 16-8 The Wave Equation 425
- The Principle of Superposition for Waves 426 16-9
- Interference of Waves 427 16-10
- 16-11 Phasors 429
- 16-12 Standing Waves 431
- Standing Waves and Resonance 433 16-13

Review & Summary 436

Questions 436 / Problems 438

Longitudinal Waves 445

What causes the musical echo from the stairs at an ancient Mayan pyramid?

- 17-1 What Is Physics? 446
- Sound Waves 446 17-2
- The Speed of Sound 446 17-3
- Traveling Sound Waves 449 17-4
- Interference 451 17-5
- Intensity and Sound Level 453 17-6
- Sources of Musical Sound 457 17-7
- Beats 459 17-8
- The Doppler Effect 460 17-9
- Supersonic Speeds, Shock Waves 464 17-10

Review & Summary 465

Questions 466 / Problems 467

First Law of Thermodynamics 476

How can a beetle detect a forest fire at a large distance without seeing or smelling it?

- What Is Physics? 477 18-1
- 18-2 Temperature 477
- The Zeroth Law of Thermodynamics 477 18-3
- Measuring Temperature 478 18-4
- The Celsius and Fahrenheit Scales 478 18-5

Kinetic Theory 507

Questions 498 / Problems 500

What causes the fog that appears when a carbonated drink is opened?

19-1 What Is Physics? 508

19-2 Avogadro's Number 508

19-3 Ideal Gases 509

19-4 Pressure, Temperature, and RMS Speed 512

19-5 Translational Kinetic Energy 514

19-6 Mean Free Path 515

19-7 The Distribution of Molecular Speeds 517

19-8 The Molar Specific Heats of an Ideal Gas 520

19-9 Degrees of Freedom and Molar Specific Heats 523

19-10 A Hint of Quantum Theory 525

19-11 The Adiabatic Expansion of an Ideal Gas 526

Review & Summary 529

Questions 530 / Problems 531

Second Law of Thermodynamics 536

What is the connection between a rubber band's stretch and the direction of time?

20-1 What Is Physics? 537

20-2 Irreversible Processes and Entropy 537

20-3 Change in Entropy 538

20-4 The Second Law of Thermodynamics 542

20-5 Entropy in the Real World: Engines 543

20-6 Entropy in the Real World: Refrigerators 548

20-7 The Efficiencies of Real Engines 549

20-8 A Statistical View of Entropy 550

Review & Summary 554

Questions 555 / Problems 555

Coulomb's Law 561

How can a video monitor in a surgical room increase the risk of bacterial contamination?

21-1 What Is Physics? 562

21-2 Electric Charge 562

21-3 Conductors and Insulators 563

21-4 Coulomb's Law 565

21-5 Charge Is Quantized 571

21-6 Charge Is Conserved 572

Review & Summary 573

Questions 573 / Problems 575

Finding the Electric Field—I 580

How does a bee use electrostatics to collect and then distribute pollen grains?

22-1 What Is Physics? 581

22-2 The Electric Field 581

22-3 Electric Field Lines 582

22-4 The Electric Field Due to a Point Charge 583

22-5 The Electric Field Due to an Electric Dipole 585

22-6 The Electric Field Due to a Line of Charge 586

22-7 The Electric Field Due to a Charged Disk 590

22-8 A Point Charge in an Electric Field 591

22-9 A Dipole in an Electric Field 594

Review & Summary 596

Questions 597 / Problems 598

Finding the Electric Field—II 605

How can lightning harm you even if it does not strike you?

23-1 What Is Physics? 606

23-2 Flux 606

23-3 Flux of an Electric Field 607

23-4 Gauss' Law 609

23-5 Gauss' Law and Coulomb's Law 611

23-6 A Charged Isolated Conductor 612

23-7 Applying Gauss' Law: Cylindrical Symmetry 615

23-8 Applying Gauss' Law: Planar Symmetry 616

23-9 Applying Gauss' Law: Spherical Symmetry 618

Review & Summary 620

Questions 620 / Problems 621

Finding the Electric Potential 628

What danger does a sweater pose to a computer?

24-1 What Is Physics? 629

24-2 Electric Potential Energy 629

24-3 Electric Potential 630

24-6	Potential Due to a Point Charge 635
24-7	Potential Due to a Group of Point
	Charges 636
24-8	Potential Due to an Electric Dipole 637
24-9	Potential Due to a Continuous Charge
	Distribution 638
24-10	
24-11	
	Charges 641
24-12	
	w & Summary 645
Quest	ions 646 / Problems 647
2510	Capacitors and Capacitance 656
Howc	an a spark set up an explosion in airborne powder?
25-1	What Is Physics? 657
25-2	Capacitance 657
25-3	Calculating the Capacitance 659
25-4	Capacitors in Parallel and in Series 662
25-5	Energy Stored in an Electric Field 666
25-6	Capacitor with a Dielectric 670
25-7	Dielectrics: An Atomic View 672
25-8	Dielectrics and Gauss' Law 672
Review	& Summary 675
	ons 675 / Problems 676
240	hm's Law 682
	recautions should you take if caught outdoors
	a lightning storm?
26-1	What Is Physics? 683
26-2	Electric Current 683
26-3	Current Density 685
26-4	Resistance and Resistivity 688
26-5	Ohm's Law 692
26-6	A Microscopic View of Ohm's Law 693
26-7	Power in Electric Circuits 695
26-8	Semiconductors 696
26-9	Superconductors 697
	Summary 698
Question	ns 699 / Problems 700
NAME OF THE OWNER, OWNE	
Cir	cuit Theory 705
How can	a pit crew avoid a fire while fueling a

Equipotential Surfaces 632

Calculating the Potential from the Field 633

24-4

charged race car?

What Is Physics? 706

"Pumping" Charges 706

27-1

27-2

27-5 Other Single-Loop Circuits 710 Potential Difference Between Two 27-6 Points 711 27-7 Multiloop Circuits 714 27-8 The Ammeter and the Voltmeter 720 27-9 RC Circuits 720 Review & Summary 724 Questions 725 / Problems 726 Magnetic Force 735 What causes an aurora and why is it so thin? 28-1 What Is Physics? 736 28-2 What Produces a Magnetic Field? 736 28-3 The Definition of B 736 28-4 Crossed Fields: Discovery of the Electron 740 28-5 Crossed Fields: The Hall Effect 741 28-6 A Circulating Charged Particle 743 28-7 Cyclotrons and Synchrotrons 748 28-8 Magnetic Force on a Current-Carrying

Work, Energy, and Emf 707

Calculating the Current in a

Single-Loop Circuit 708

27-3

27-4

Current-Produced Magnetic Fields 764

Torque on a Current Loop 752 The Magnetic Dipole Moment 754

How can the human brain produce a detectable magnetic

field without any magnetic material? 29-1 What Is Physics? 765 29-2 Calculating the Magnetic Field Due to a Current 765 29-3 Force Between Two Parallel Currents 771 29-4 Ampere's Law 772 Solenoids and Toroids 776 29-5 A Current-Carrying Coil as a 29-6 Magnetic Dipole 778 Review & Summary 780 Questions 781 / Problems 782

10 Inductance 791

Wire 750

Review & Summary 755

Questions 756 / Problems 757

28-9

How can magnetic induction melt metal in a foundry?

30-1 What Is Physics? 792

30-2 Two Experiments 792

	Sometics		
30-3 30-4 30-5 30-6 30-7	Faraday's Law of Induction 793 Lenz's Law 795 Induction and Energy Transfers 798 Induced Electric Fields 801 Inductors and Inductance 805	32-7 32-8 32-9 32-10 32-11	Magnetism and Magnetic Mate Diamagnetism Paramagnetism Ferromagnetis
30-8	Self-Induction 806		& Summary 88
30-9	RL Circuits 807 Energy Stored in a Magnetic Field 810	Questio	ons 882 / Pro
30-11	Energy Density of a Magnetic Field 812	KKIN	lature of Ele
	Mutual Induction 814 & Summary 816	appear	auses a sundog left or right of
Questi	ons 816 / Problems 818	33-1	What Is Physic Maxwell's Rain

Alternating Fields and Current 826

How did a solar eruption knock out the power-

ginu sy	stell of Quebec:
31-1	What Is Physics? 827
31-2	LC Oscillations, Qualitatively 827
31-3	The Electrical–Mechanical
	Analogy 830
31-4	LC Oscillations, Quantitatively 831

31-5	Damped Oscillations in an n		
	Circuit 834		
31-6	Alternating Current	835	
31-7	Forced Oscillations	835	

31-8 Three Simple Circuits 837 31-9 The Series RLC Circuit 842 31-10 Power in Alternating-Current Circuits 846

Transformers 849 31-11

Review & Summary 853

Questions 854 / Problems 855

Maxwell's Equations, Models of Magnetism 861

How can a mural painting record the direction

of Eart	h's magnetic field?
32-1	What Is Physics? 862
32-2	Gauss' Law for Magnetic Fields 862
32-3	Induced Magnetic Fields 864
32-4	Displacement Current 866
32-5	Maxwell's Equations 868
32.6	Magnete 0/0

32-7	Magnetism and Electrons 870
32-8	Magnetic Materials 874
32-9	Diamagnetism 874
32-10	Paramagnetism 876
32-11	Ferromagnetism 877
Review	& Summary 881
Questio	ns 882 / Problems 883

ectromagnetic Waves 889

the bright, colorful spot that can

33-1	What Is Physics? 890
33-2	Maxwell's Rainbow 890
33-3	The Traveling Electromagnetic Wave,
	Qualitatively 891
33-4	The Traveling Electromagnetic Wave,
	Quantitatively 894
33-5	Energy Transport and the Poynting Vector 897
33-6	Radiation Pressure 899
33-7	Polarization 901
33-8	Reflection and Refraction 905
33-9	Total Internal Reflection 910
33-10	Polarization by Reflection 912
Review	& Summary 913

K2 Geometric Optics 924

Questions 914 / Problems 915

How can a fish see clearly in both air and water

simultaneously?		
34-1	What Is Physics? 925	
34-2	Two Types of Image 925	
34-3	Plane Mirrors 926	
34-4	Spherical Mirrors 928	
34-5	Images from Spherical Mirrors 930	
34-6	Spherical Refracting Surfaces 933	
34-7	Thin Lenses 936	
34-8	Optical Instruments 941	
34-9	Three Proofs 944	
Review & Summary 947		
Questio	ons 948 / Problems 949	

Optical Interference 958

How do color-shifting inks on paper currency shift colors?

What Is Physics? 959 35-1 35-2 Light as a Wave 959

35-3 Diffraction 963	kill Light Quanta, Matter Waves 1057
35-4 Young's Interference Experiment 964	How can molecules be moved one by one and
35-5 Coherence 968	then imaged?
35-6 Intensity in Double-Slit Interference 968	38-1 What is Physics? 1058
35-7 Interference from Thin Films 972	38-2 The Photon, the Quantum of Light 1058
35-8 Michelson's Interferometer 978	38-3 The Photoelectric Effect 1060
Review & Summary 979	38-4 Photons Have Momentum 1063
Questions 979 / Problems 981	38-5 Light as a Probability Wave 1066
	38-6 Electrons and Matter Waves 1068
Optical Diffraction 990	38-7 Schrödinger's Equation 1071
	38-8 Heisenberg's Uncertainty Principle 1073
What causes the arresting blue color of the facial skin of a mandrill baboon?	38-9 Barrier Tunneling 1074
36-1 What Is Physics? 991	Review & Summary 1077
36-2 Diffraction and the Wave Theory of Light 991	Questions 1077 / Problems 1078
36-3 Diffraction by a Single Slit: Locating the	
Minima 992	Matter-Wave Traps 1083
36-4 Intensity in Single-Slit Diffraction,	How can you corral an electron?
Qualitatively 995	39-1 What Is Physics? 1084
36-5 Intensity in Single-Slit Diffraction,	39-2 String Waves and Matter Waves 1084
Quantitatively 996	39-3 Energies of a Trapped Electron 1085
36-6 Diffraction by a Circular Aperture 998	39-4 Wave Functions of a Trapped Electron 1089
36-7 Diffraction by a Double Slit 1002	39-5 An Electron in a Finite Well 1092
36-8 Diffraction Gratings 1004	39-6 More Electron Traps 1094
36-9 Gratings: Dispersion and Resolving Power 1008	39-7 Two- and Three-Dimensional Electron
36-10 Diffraction by Organized Layers 1010	Traps 1096
	39-8 The Bohr Model of the Hydrogen Atom 1097
Review & Summary 1012	39-9 Schrödinger's Equation and the
Questions 1013 / Problems 1014	
	Hydrogen Atom 1100
Special Relativity 1022	Review & Summary 1106
	Questions 1107 / Problems 1108
How can we determine what lurks at the center of the	
galaxy M87, 50 million light-years away?	20 Atoms, X Rays, and Lasers 1112
37-1 What Is Physics? 1023	
37-2 The Postulates 1023	What is so different about light from a laser?
37-3 Measuring an Event 1024	40-1 What Is Physics? 1113
37-4 The Relativity of Simultaneity 1026	40-2 Some Properties of Atoms 1113
37-5 The Relativity of Time 1027	40-3 Electron Spin 1115
37-6 The Relativity of Length 1032	40-4 Angular Momenta and Magnetic
37-7 The Lorentz Transformation 1034	Dipole Moments 1116
37-8 Some Consequences of the Lorentz	40-5 The Stern–Gerlach Experiment 1118
Equations 1036	40-6 Magnetic Resonance 1121
37-9 The Relativity of Velocities 1038	40-7 The Pauli Exclusion Principle 1122
37-10 Doppler Effect for Light 1039	40-8 Multiple Electrons in Rectangular Traps 112
37-11 A New Look at Momentum 1043	40-9 Building the Periodic Table 1126
37-12 A New Look at Energy 1043	40-10 X Rays and the Ordering of the
Review & Summary 1048	Elements 1127
Questions 1049 / Problems 1050	11 11 14 1424
Zuesdons 1047 / Froblems 1050	40-11 Lasers and Laser Light 1131

40-12 How Lasers Work 1132 Review & Summary 1135 Questions 1135 / Problems 1137

Electrical Properties of Materials 1142

Why do rock guitarists shun transistor amplifiers for oldfashioned tube amplifiers?

41-1 What Is Physics? 1143

41-2 The Electrical Properties of Solids 1143

41-3 Energy Levels in a Crystalline Solid 1144

41-4 Insulators 1144

41-5 Metals 1145

41-6 Semiconductors 1150

41-7 Doped Semiconductors 1151

41-8 The p-n Junction 1154

41-9 The Junction Rectifier 1156

41-10 The Light-Emitting Diode (LED) 1157

41-11 The Transistor 1159

Review & Summary 1160

Questions 1161 / Problems 1162

Nuclear Reactions 1165

What causes the radiation danger to air crews flying the long "polar" routes?

42-1 What Is Physics? 1166

42-2 Discovering the Nucleus 1166

42-3 Some Nuclear Properties 1167

42-4 Radioactive Decay 1174

42-5 Alpha Decay 1177

42-6 Beta Decay 1179

42-7 Radioactive Dating 1182

42-8 Measuring Radiation Dosage 1183

42-9 Nuclear Models 1184

Review & Summary 1187

Questions 1188 / Problems 1188

Eki Energy from Nuclear Reactions 1195

What physics underlies the image that has horrified the world since World War II?

43-1 What Is Physics? 1196

43-2 Nuclear Fission: The Basic Process 1197

43-3 A Model for Nuclear Fission 1199

43-4 The Nuclear Reactor 1201

43-5 A Natural Nuclear Reactor 1205

43-6 Thermonuclear Fusion: The Basic Process 1207

43-7 Thermonuclear Fusion in the Sun and Other Stars 1208

43-8 Controlled Thermonuclear Fusion 1211

Review & Summary 1213

Questions 1213 / Problems 1214

Fundamental Particles, Cosmology 1218

How can a photograph of the early universe be taken?

44-1 What Is Physics? 1219

44-2 Particles, Particles, Particles 1219

44-3 An Interlude 1223

44-4 The Leptons 1226

44-5 The Hadrons 1227

44-6 Still Another Conservation Law 1229

44-7 The Eightfold Way 1230

44-8 The Quark Model 1231

44-9 The Basic Forces and Messenger Particles 1234

44-10 A Pause for Reflection 1236

44-11 The Universe Is Expanding 1237

44-12 The Cosmic Background Radiation 1238

44-13 Dark Matter 1238

44-14 The Big Bang 1239

44-15 A Summing Up 1242

Review & Summary 1242

Questions 1243 / Problems 1243

Appendices

A The International System of Units (SI) 1249

B Some Fundamental Constants of Physics 1251

C Some Astronomical Data 1252

D Conversion Factors 1253

E Mathematical Formulas 1257

F Properties of the Elements 1260

G Periodic Table of the Elements 1263

Answers to Checkpoints and Odd-Numbered Questions and Problems 1265

Index 1279