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# PHYSICS

for  
SCIENTISTS & ENGINEERS  
with Modern Physics

DOUGLAS C. GIANCOLI



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# Contents



APPLICATIONS LIST  
PREFACE  
TO STUDENTS  
USE OF COLOR

xii  
xiv  
xviii  
xix

## Volume 1

### 1 INTRODUCTION, MEASUREMENT, ESTIMATING 1

1-1	The Nature of Science	2
1-2	Models, Theories, and Laws	2
1-3	Measurement and Uncertainty; Significant Figures	3
1-4	Units, Standards, and the SI System	6
1-5	Converting Units	8
1-6	Order of Magnitude: Rapid Estimating	9
*1-7	Dimensions and Dimensional Analysis	12
SUMMARY 14		QUESTIONS 14
PROBLEMS 14		GENERAL PROBLEMS 16

### 2 DESCRIBING MOTION: KINEMATICS IN ONE DIMENSION 18

2-1	Reference Frames and Displacement	19
2-2	Average Velocity	20
2-3	Instantaneous Velocity	22
2-4	Acceleration	24
2-5	Motion at Constant Acceleration	28
2-6	Solving Problems	30
2-7	Freely Falling Objects	34
*2-8	Variable Acceleration; Integral Calculus	39
*2-9	Graphical Analysis and Numerical Integration	40
SUMMARY 43		QUESTIONS 43
PROBLEMS 44		GENERAL PROBLEMS 48

### 3 KINEMATICS IN TWO OR THREE DIMENSIONS; VECTORS 51

3-1	Vectors and Scalars	52
3-2	Addition of Vectors—Graphical Methods	52
3-3	Subtraction of Vectors, and Multiplication of a Vector by a Scalar	54
3-4	Adding Vectors by Components	55
3-5	Unit Vectors	59
3-6	Vector Kinematics	59
3-7	Projectile Motion	62
3-8	Solving Problems: Projectile Motion	64
3-9	Relative Velocity	71
SUMMARY 74		QUESTIONS 75
PROBLEMS 75		GENERAL PROBLEMS 80

### 4 DYNAMICS: NEWTON'S LAWS OF MOTION 83

4-1	Force	84
4-2	Newton's First Law of Motion	84
4-3	Mass	86
4-4	Newton's Second Law of Motion	86
4-5	Newton's Third Law of Motion	89
4-6	Weight—the Force of Gravity; the Normal Force	92
4-7	Solving Problems with Newton's Laws: Free-Body Diagrams	95
4-8	Problem Solving—A General Approach	102
SUMMARY 102		QUESTIONS 103
PROBLEMS 104		GENERAL PROBLEMS 109

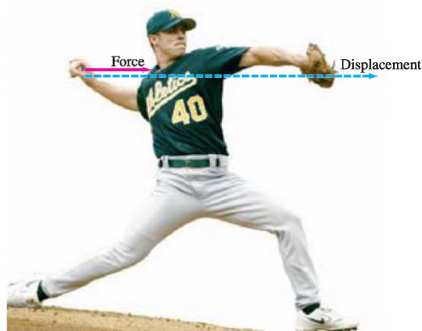
### 5 USING NEWTON'S LAWS: FRICTION, CIRCULAR MOTION, DRAG FORCES 112

5-1	Applications of Newton's Laws Involving Friction	113
5-2	Uniform Circular Motion—Kinematics	119
5-3	Dynamics of Uniform Circular Motion	122
5-4	Highway Curves: Banked and Unbanked	126
*5-5	Nonuniform Circular Motion	128
*5-6	Velocity-Dependent Forces: Drag and Terminal Velocity	129
SUMMARY 130		QUESTIONS 131
PROBLEMS 132		GENERAL PROBLEMS 136



## 6 GRAVITATION AND NEWTON'S SYNTHESIS 139

- 6-1 Newton's Law of Universal Gravitation 140
- 6-2 Vector Form of Newton's Law of Universal Gravitation 143
- 6-3 Gravity Near the Earth's Surface; Geophysical Applications 143
- 6-4 Satellites and "Weightlessness" 146
- 6-5 Kepler's Laws and Newton's Synthesis 149
- \*6-6 Gravitational Field 154
- 6-7 Types of Forces in Nature 155
- \*6-8 Principle of Equivalence; Curvature of Space; Black Holes 155
- SUMMARY 157 QUESTIONS 157
- PROBLEMS 158 GENERAL PROBLEMS 160



## 7 WORK AND ENERGY 163

- 7-1 Work Done by a Constant Force 164
- 7-2 Scalar Product of Two Vectors 167
- 7-3 Work Done by a Varying Force 168
- 7-4 Kinetic Energy and the Work-Energy Principle 172
- SUMMARY 176 QUESTIONS 177
- PROBLEMS 177 GENERAL PROBLEMS 180

## 8 CONSERVATION OF ENERGY 183

- 8-1 Conservative and Nonconservative Forces 184
- 8-2 Potential Energy 186
- 8-3 Mechanical Energy and Its Conservation 189
- 8-4 Problem Solving Using Conservation of Mechanical Energy 190
- 8-5 The Law of Conservation of Energy 196
- 8-6 Energy Conservation with Dissipative Forces: Solving Problems 197
- 8-7 Gravitational Potential Energy and Escape Velocity 199
- 8-8 Power 201
- \*8-9 Potential Energy Diagrams; Stable and Unstable Equilibrium 204
- SUMMARY 205 QUESTIONS 205
- PROBLEMS 207 GENERAL PROBLEMS 211

## 9 LINEAR MOMENTUM 214

- 9-1 Momentum and Its Relation to Force 215
- 9-2 Conservation of Momentum 217
- 9-3 Collisions and Impulse 220
- 9-4 Conservation of Energy and Momentum in Collisions 222
- 9-5 Elastic Collisions in One Dimension 222
- 9-6 Inelastic Collisions 225
- 9-7 Collisions in Two or Three Dimensions 227
- 9-8 Center of Mass (CM) 230
- 9-9 Center of Mass and Translational Motion 234
- \*9-10 Systems of Variable Mass; Rocket Propulsion 236
- SUMMARY 239 QUESTIONS 239
- PROBLEMS 240 GENERAL PROBLEMS 245

## 10 ROTATIONAL MOTION 248

- 10-1 Angular Quantities 249
- 10-2 Vector Nature of Angular Quantities 254
- 10-3 Constant Angular Acceleration 255
- 10-4 Torque 256
- 10-5 Rotational Dynamics; Torque and Rotational Inertia 258
- 10-6 Solving Problems in Rotational Dynamics 260
- 10-7 Determining Moments of Inertia 263
- 10-8 Rotational Kinetic Energy 265
- 10-9 Rotational Plus Translational Motion; Rolling 267
- \*10-10 Why Does a Rolling Sphere Slow Down? 273
- SUMMARY 274 QUESTIONS 275
- PROBLEMS 276 GENERAL PROBLEMS 281

## 11 ANGULAR MOMENTUM; GENERAL ROTATION 284

- 11-1 Angular Momentum—Objects Rotating About a Fixed Axis 285
- 11-2 Vector Cross Product; Torque as a Vector 289
- 11-3 Angular Momentum of a Particle 291
- 11-4 Angular Momentum and Torque for a System of Particles; General Motion 292
- 11-5 Angular Momentum and Torque for a Rigid Object 294
- 11-6 Conservation of Angular Momentum 297
- \*11-7 The Spinning Top and Gyroscope 299
- \*11-8 Rotating Frames of Reference; Inertial Forces 300
- \*11-9 The Coriolis Effect 301

SUMMARY 302  
QUESTIONS 303  
PROBLEMS 303  
GENERAL  
PROBLEMS 308





## 12 STATIC EQUILIBRIUM; ELASTICITY AND FRACTURE 311

12-1	The Conditions for Equilibrium	312
12-2	Solving Statics Problems	313
12-3	Stability and Balance	317
12-4	Elasticity; Stress and Strain	318
12-5	Fracture	322
*12-6	Trusses and Bridges	324
*12-7	Arches and Domes	327
SUMMARY 329		QUESTIONS 329
PROBLEMS 330		GENERAL PROBLEMS 334

## 13 FLUIDS 339

13-1	Phases of Matter	340
13-2	Density and Specific Gravity	340
13-3	Pressure in Fluids	341
13-4	Atmospheric Pressure and Gauge Pressure	345
13-5	Pascal's Principle	346
13-6	Measurement of Pressure; Gauges and the Barometer	346
13-7	Buoyancy and Archimedes' Principle	348
13-8	Fluids in Motion; Flow Rate and the Equation of Continuity	352
13-9	Bernoulli's Equation	354
13-10	Applications of Bernoulli's Principle: Torricelli, Airplanes, Baseballs, TIA	356
*13-11	Viscosity	358
*13-12	Flow in Tubes: Poiseuille's Equation, Blood Flow	358
*13-13	Surface Tension and Capillarity	359
*13-14	Pumps, and the Heart	361
SUMMARY 361		QUESTIONS 362
PROBLEMS 363		GENERAL PROBLEMS 367

## 14 OSCILLATIONS 369

14-1	Oscillations of a Spring	370
14-2	Simple Harmonic Motion	372
14-3	Energy in the Simple Harmonic Oscillator	377
14-4	Simple Harmonic Motion Related to Uniform Circular Motion	379
14-5	The Simple Pendulum	379
*14-6	The Physical Pendulum and the Torsion Pendulum	381
14-7	Damped Harmonic Motion	382
14-8	Forced Oscillations; Resonance	385
SUMMARY 387		QUESTIONS 388
PROBLEMS 388		GENERAL PROBLEMS 392

## 15 WAVE MOTION 395

15-1	Characteristics of Wave Motion	396
15-2	Types of Waves: Transverse and Longitudinal	398
15-3	Energy Transported by Waves	402
15-4	Mathematical Representation of a Traveling Wave	404
*15-5	The Wave Equation	406
15-6	The Principle of Superposition	408
15-7	Reflection and Transmission	409
15-8	Interference	410
15-9	Standing Waves; Resonance	412
*15-10	Refraction	415
*15-11	Diffraction	416
SUMMARY 417		QUESTIONS 417
PROBLEMS 418		GENERAL PROBLEMS 422

## 16 SOUND 424

16-1	Characteristics of Sound	425
16-2	Mathematical Representation of Longitudinal Waves	426
16-3	Intensity of Sound: Decibels	427
16-4	Sources of Sound: Vibrating Strings and Air Columns	431
*16-5	Quality of Sound, and Noise; Superposition	436
16-6	Interference of Sound Waves; Beats	437
16-7	Doppler Effect	439
*16-8	Shock Waves and the Sonic Boom	443
*16-9	Applications: Sonar, Ultrasound, and Medical Imaging	444
SUMMARY 446		QUESTIONS 447
PROBLEMS 448		GENERAL PROBLEMS 451





## 19 HEAT AND THE FIRST LAW OF THERMODYNAMICS 496

19-1	Heat as Energy Transfer	497
19-2	Internal Energy	498
19-3	Specific Heat	499
19-4	Calorimetry—Solving Problems	500
19-5	Latent Heat	502
19-6	The First Law of Thermodynamics	505
19-7	The First Law of Thermodynamics Applied; Calculating the Work	507
19-8	Molar Specific Heats for Gases, and the Equipartition of Energy	511
19-9	Adiabatic Expansion of a Gas	514
19-10	Heat Transfer: Conduction, Convection, Radiation	515
	SUMMARY 520 QUESTIONS 521	
	PROBLEMS 522 GENERAL PROBLEMS 526	

## 20 SECOND LAW OF THERMODYNAMICS 528

20-1	The Second Law of Thermodynamics—Introduction	529
20-2	Heat Engines	530
20-3	Reversible and Irreversible Processes; the Carnot Engine	533
20-4	Refrigerators, Air Conditioners, and Heat Pumps	536
20-5	Entropy	539
20-6	Entropy and the Second Law of Thermodynamics	541
20-7	Order to Disorder	544
20-8	Unavailability of Energy; Heat Death	545
*20-9	Statistical Interpretation of Entropy and the Second Law	546
*20-10	Thermodynamic Temperature; Third Law of Thermodynamics	548
*20-11	Thermal Pollution, Global Warming, and Energy Resources	549
	SUMMARY 551 QUESTIONS 552	
	PROBLEMS 552 GENERAL PROBLEMS 556	



## 17 TEMPERATURE, THERMAL EXPANSION, AND THE IDEAL GAS LAW 454

17-1	Atomic Theory of Matter	455
17-2	Temperature and Thermometers	456
17-3	Thermal Equilibrium and the Zeroth Law of Thermodynamics	459
17-4	Thermal Expansion	459
*17-5	Thermal Stresses	463
17-6	The Gas Laws and Absolute Temperature	463
17-7	The Ideal Gas Law	465
17-8	Problem Solving with the Ideal Gas Law	466
17-9	Ideal Gas Law in Terms of Molecules; Avogadro's Number	468
*17-10	Ideal Gas Temperature Scale—a Standard	469
	SUMMARY 470 QUESTIONS 471	
	PROBLEMS 471 GENERAL PROBLEMS 474	

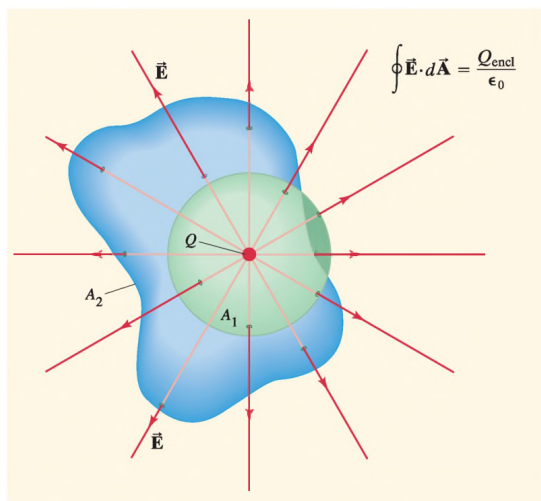
## 18 KINETIC THEORY OF GASES 476

18-1	The Ideal Gas Law and the Molecular Interpretation of Temperature	476
18-2	Distribution of Molecular Speeds	480
18-3	Real Gases and Changes of Phase	482
18-4	Vapor Pressure and Humidity	484
*18-5	Van der Waals Equation of State	486
*18-6	Mean Free Path	487
*18-7	Diffusion	489
	SUMMARY 490 QUESTIONS 491	
	PROBLEMS 492 GENERAL PROBLEMS 494	

# Volume 2

## 21 ELECTRIC CHARGE AND ELECTRIC FIELD 559

21-1	Static Electricity; Electric Charge and Its Conservation	560
21-2	Electric Charge in the Atom	561
21-3	Insulators and Conductors	561
21-4	Induced Charge; the Electroscope	562
21-5	Coulomb's Law	563
21-6	The Electric Field	568
21-7	Electric Field Calculations for Continuous Charge Distributions	572
21-8	Field Lines	575
21-9	Electric Fields and Conductors	577
21-10	Motion of a Charged Particle in an Electric Field	578
21-11	Electric Dipoles	579
*21-12	Electric Forces in Molecular Biology; DNA	581
*21-13	Photocopy Machines and Computer Printers Use Electrostatics	582
	SUMMARY 584 QUESTIONS 584	
	PROBLEMS 585 GENERAL PROBLEMS 589	



## 22 GAUSS'S LAW 591

22-1	Electric Flux	592
22-2	Gauss's Law	593
22-3	Applications of Gauss's Law	595
*22-4	Experimental Basis of Gauss's and Coulomb's Laws	600
	SUMMARY 601 QUESTIONS 601	
	PROBLEMS 601 GENERAL PROBLEMS 605	

## 23 ELECTRIC POTENTIAL 607

23-1	Electric Potential Energy and Potential Difference	607
23-2	Relation between Electric Potential and Electric Field	610
23-3	Electric Potential Due to Point Charges	612
23-4	Potential Due to Any Charge Distribution	614
23-5	Equipotential Surfaces	616
23-6	Electric Dipole Potential	617
23-7	$\vec{E}$ Determined from $V$	617
23-8	Electrostatic Potential Energy; the Electron Volt	619
*23-9	Cathode Ray Tube: TV and Computer Monitors, Oscilloscope	620
	SUMMARY 622 QUESTIONS 622	
	PROBLEMS 623 GENERAL PROBLEMS 626	

## 24 CAPACITANCE, DIELECTRICS, ELECTRIC ENERGY STORAGE 628

24-1	Capacitors	628
24-2	Determination of Capacitance	630
24-3	Capacitors in Series and Parallel	633
24-4	Electric Energy Storage	636
24-5	Dielectrics	638
*24-6	Molecular Description of Dielectrics	640
	SUMMARY 643 QUESTIONS 643	
	PROBLEMS 644 GENERAL PROBLEMS 648	

## 25 ELECTRIC CURRENTS AND RESISTANCE 651

25-1	The Electric Battery	652
25-2	Electric Current	654
25-3	Ohm's Law: Resistance and Resistors	655
25-4	Resistivity	658
25-5	Electric Power	660
25-6	Power in Household Circuits	662
25-7	Alternating Current	664
25-8	Microscopic View of Electric Current: Current Density and Drift Velocity	666
*25-9	Superconductivity	668
*25-10	Electrical Conduction in the Nervous System	669
	SUMMARY 671 QUESTIONS 671	
	PROBLEMS 672 GENERAL PROBLEMS 675	

## 26 DC CIRCUITS 677

26-1	EMF and Terminal Voltage	678
26-2	Resistors in Series and in Parallel	679
26-3	Kirchhoff's Rules	683
26-4	Series and Parallel EMFs; Battery Charging	686
26-5	Circuits Containing Resistor and Capacitor ( $RC$ Circuits)	687
26-6	Electric Hazards	692
*26-7	Ammeters and Voltmeters	695
	SUMMARY 698 QUESTIONS 698	
	PROBLEMS 699 GENERAL PROBLEMS 704	



## 27 MAGNETISM 707

27-1	Magnets and Magnetic Fields	707
27-2	Electric Currents Produce Magnetic Fields	710
27-3	Force on an Electric Current in a Magnetic Field; Definition of $\vec{B}$	710
27-4	Force on an Electric Charge Moving in a Magnetic Field	714
27-5	Torque on a Current Loop; Magnetic Dipole Moment	718
*27-6	Applications: Motors, Loudspeakers, Galvanometers	720
27-7	Discovery and Properties of the Electron	721
27-8	The Hall Effect	723
*27-9	Mass Spectrometer	724
SUMMARY		725
QUESTIONS		726
PROBLEMS		727
GENERAL PROBLEMS		730

## 28 SOURCES OF MAGNETIC FIELD 733

28-1	Magnetic Field Due to a Straight Wire	734
28-2	Force between Two Parallel Wires	735
28-3	Definitions of the Ampere and the Coulomb	736
28-4	Ampère's Law	737
28-5	Magnetic Field of a Solenoid and a Toroid	741
28-6	Biot-Savart Law	743
28-7	Magnetic Materials—Ferromagnetism	746
*28-8	Electromagnets and Solenoids—Applications	747
*28-9	Magnetic Fields in Magnetic Materials; Hysteresis	748
*28-10	Paramagnetism and Diamagnetism	749
SUMMARY		750
QUESTIONS		751
PROBLEMS		751
GENERAL PROBLEMS		755

## 29 ELECTROMAGNETIC INDUCTION AND FARADAY'S LAW 758

29-1	Induced EMF	759
29-2	Faraday's Law of Induction; Lenz's Law	760
29-3	EMF Induced in a Moving Conductor	765
29-4	Electric Generators	766
*29-5	Back EMF and Counter Torque; Eddy Currents	768
29-6	Transformers and Transmission of Power	770
29-7	A Changing Magnetic Flux Produces an Electric Field	773
*29-8	Applications of Induction: Sound Systems, Computer Memory, Seismograph, GFCI	775
SUMMARY		777
QUESTIONS		777
PROBLEMS		778
GENERAL PROBLEMS		782

## 30 INDUCTANCE, ELECTROMAGNETIC OSCILLATIONS, AND AC CIRCUITS 785

30-1	Mutual Inductance	786
30-2	Self-Inductance	788
30-3	Energy Stored in a Magnetic Field	790
30-4	$LR$ Circuits	790
30-5	$LC$ Circuits and Electromagnetic Oscillations	793
30-6	$LC$ Oscillations with Resistance ( $LRC$ Circuit)	795
30-7	AC Circuits with AC Source	796
30-8	$LRC$ Series AC Circuit	799
30-9	Resonance in AC Circuits	802
*30-10	Impedance Matching	802
*30-11	Three-Phase AC	803
SUMMARY		804
QUESTIONS		804
PROBLEMS		805
GENERAL PROBLEMS		809

## 31 MAXWELL'S EQUATIONS AND ELECTROMAGNETIC WAVES 812

31-1	Changing Electric Fields Produce Magnetic Fields; Ampère's Law and Displacement Current	813
31-2	Gauss's Law for Magnetism	816
31-3	Maxwell's Equations	817
31-4	Production of Electromagnetic Waves	817
31-5	Electromagnetic Waves, and Their Speed, from Maxwell's Equations	819
31-6	Light as an Electromagnetic Wave and the Electromagnetic Spectrum	823
31-7	Measuring the Speed of Light	825
31-8	Energy in EM Waves; the Poynting Vector	826
31-9	Radiation Pressure	828
31-10	Radio and Television; Wireless Communication	829
SUMMARY		832
QUESTIONS		832
PROBLEMS		833
GENERAL PROBLEMS		835



## 32 LIGHT: REFLECTION AND REFRACTION 837

32-1	The Ray Model of Light	838
32-2	Reflection; Image Formation by a Plane Mirror	838
32-3	Formation of Images by Spherical Mirrors	842
32-4	Index of Refraction	850
32-5	Refraction: Snell's Law	850
32-6	Visible Spectrum and Dispersion	852
32-7	Total Internal Reflection; Fiber Optics	854
*32-8	Refraction at a Spherical Surface	856
	SUMMARY 858 QUESTIONS 859	
	PROBLEMS 860 GENERAL PROBLEMS 864	



## 34 THE WAVE NATURE OF LIGHT; INTERFERENCE 900

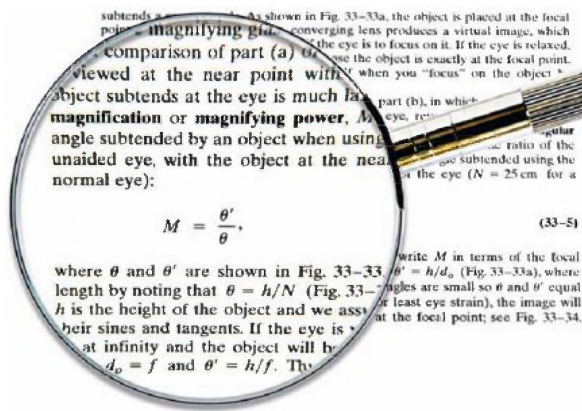
34-1	Waves Versus Particles; Huygens' Principle and Diffraction	901
34-2	Huygens' Principle and the Law of Refraction	902
34-3	Interference—Young's Double-Slit Experiment	903
*34-4	Intensity in the Double-Slit Interference Pattern	906
34-5	Interference in Thin Films	909
*34-6	Michelson Interferometer	914
*34-7	Luminous Intensity	915
	SUMMARY 915 QUESTIONS 916	
	PROBLEMS 916 GENERAL PROBLEMS 918	

## 35 DIFFRACTION AND POLARIZATION 921

35-1	Diffraction by a Single Slit or Disk	922
*35-2	Intensity in Single-Slit Diffraction Pattern	924
*35-3	Diffraction in the Double-Slit Experiment	927
35-4	Limits of Resolution; Circular Apertures	929
35-5	Resolution of Telescopes and Microscopes; the $\lambda$ Limit	931
*35-6	Resolution of the Human Eye and Useful Magnification	932
35-7	Diffraction Grating	933
35-8	The Spectrometer and Spectroscopy	935
*35-9	Peak Widths and Resolving Power for a Diffraction Grating	937
35-10	X-Rays and X-Ray Diffraction	938
35-11	Polarization	940
*35-12	Liquid Crystal Displays (LCD)	943
*35-13	Scattering of Light by the Atmosphere	945
	SUMMARY 945 QUESTIONS 946	
	PROBLEMS 946 GENERAL PROBLEMS 949	

## 33 LENSES AND OPTICAL INSTRUMENTS 866

33-1	Thin Lenses; Ray Tracing	867
33-2	The Thin Lens Equation; Magnification	870
33-3	Combinations of Lenses	874
*33-4	Lensmaker's Equation	876
33-5	Cameras: Film and Digital	878
33-6	The Human Eye; Corrective Lenses	882
33-7	Magnifying Glass	885
33-8	Telescopes	887
*33-9	Compound Microscope	890
*33-10	Aberrations of Lenses and Mirrors	891
	SUMMARY 892 QUESTIONS 893	
	PROBLEMS 894 GENERAL PROBLEMS 897	



# Volume 3

## 36 SPECIAL THEORY OF RELATIVITY 951

36-1	Galilean–Newtonian Relativity	952
*36-2	The Michelson–Morley Experiment	954
36-3	Postulates of the Special Theory of Relativity	957
36-4	Simultaneity	958
36-5	Time Dilation and the Twin Paradox	960
36-6	Length Contraction	964
36-7	Four-Dimensional Space–Time	967
36-8	Galilean and Lorentz Transformations	968
36-9	Relativistic Momentum and Mass	971
36-10	The Ultimate Speed	974
36-11	$E = mc^2$ ; Mass and Energy	974
*36-12	Doppler Shift for Light	978
36-13	The Impact of Special Relativity	980
	SUMMARY	981
	QUESTIONS	981
	PROBLEMS	982
	GENERAL PROBLEMS	985

## 37 EARLY QUANTUM THEORY AND MODELS OF THE ATOM 987

37-1	Blackbody Radiation; Planck's Quantum Hypothesis	987
37-2	Photon Theory; Photoelectric Effect	989
37-3	Photon Energy, Mass, and Momentum	993
37-4	Compton Effect	994
37-5	Photon Interactions; Pair Production	996
37-6	Wave–Particle Duality; the Principle of Complementarity	997
37-7	Wave Nature of Matter	997
*37-8	Electron Microscopes	1000
37-9	Early Models of the Atom	1000
37-10	Atomic Spectra: Key to Atomic Structure	1001
37-11	The Bohr Model	1003
37-12	deBroglie's Hypothesis Applied to Atoms	1009
	SUMMARY	1010
	QUESTIONS	1011
	PROBLEMS	1012
	GENERAL PROBLEMS	1014

## 38 QUANTUM MECHANICS 1017

38-1	Quantum Mechanics—A New Theory	1018
38-2	The Wave Function and Its Interpretation; the Double-Slit Experiment	1018
38-3	The Heisenberg Uncertainty Principle	1020
38-4	Philosophic Implications; Probability Versus Determinism	1024
38-5	The Schrödinger Equation in One Dimension—Time-Independent Form	1025
*38-6	Time-Dependent Schrödinger Equation	1027
38-7	Free Particles; Plane Waves and Wave Packets	1028
38-8	Particle in an Infinitely Deep Square Well Potential (a Rigid Box)	1030
38-9	Finite Potential Well	1035
38-10	Tunneling through a Barrier	1036
	SUMMARY	1039
	QUESTIONS	1039
	PROBLEMS	1040
	GENERAL PROBLEMS	1042

### x CONTENTS



## 39 QUANTUM MECHANICS OF ATOMS 1044

39-1	Quantum-Mechanical View of Atoms	1045
39-2	Hydrogen Atom: Schrödinger Equation and Quantum Numbers	1045
39-3	Hydrogen Atom Wave Functions	1049
39-4	Complex Atoms; the Exclusion Principle	1052
39-5	Periodic Table of Elements	1053
39-6	X-Ray Spectra and Atomic Number	1054
*39-7	Magnetic Dipole Moment; Total Angular Momentum	1057
39-8	Fluorescence and Phosphorescence	1060
39-9	Lasers	1061
*39-10	Holography	1064
	SUMMARY	1066
	QUESTIONS	1066
	PROBLEMS	1067
	GENERAL PROBLEMS	1069

## 40 MOLECULES AND SOLIDS 1071

40-1	Bonding in Molecules	1071
40-2	Potential-Energy Diagrams for Molecules	1074
40-3	Weak (van der Waals) Bonds	1077
40-4	Molecular Spectra	1080
40-5	Bonding in Solids	1085
40-6	Free-Electron Theory of Metals; Fermi Energy	1086
40-7	Band Theory of Solids	1090
40-8	Semiconductors and Doping	1093
40-9	Semiconductor Diodes	1094
40-10	Transistors and Integrated Circuits (Chips)	1097
	SUMMARY	1098
	QUESTIONS	1099
	PROBLEMS	1099
	GENERAL PROBLEMS	1102

## 41 NUCLEAR PHYSICS AND RADIOACTIVITY 1104

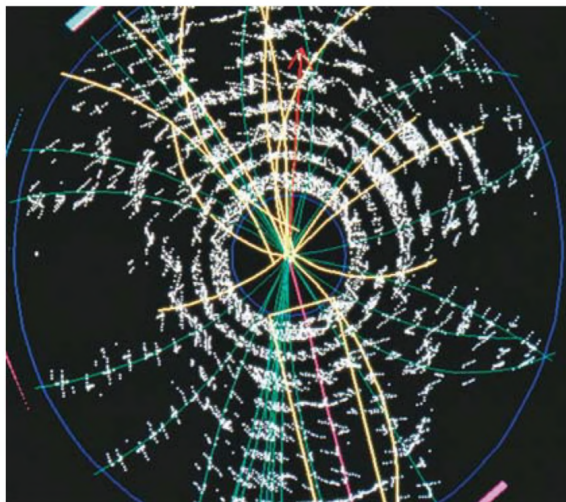
- 41-1 Structure and Properties of the Nucleus 1105
- 41-2 Binding Energy and Nuclear Forces 1108
- 41-3 Radioactivity 1110
- 41-4 Alpha Decay 1111
- 41-5 Beta Decay 1114
- 41-6 Gamma Decay 1116
- 41-7 Conservation of Nucleon Number and Other Conservation Laws 1117
- 41-8 Half-Life and Rate of Decay 1117
- 41-9 Decay Series 1121
- 41-10 Radioactive Dating 1122
- 41-11 Detection of Radiation 1124

SUMMARY 1126 QUESTIONS 1126  
PROBLEMS 1127 GENERAL PROBLEMS 1129

## 42 NUCLEAR ENERGY; EFFECTS AND USES OF RADIATION 1131

- 42-1 Nuclear Reactions and the Transmutation of Elements 1132
- 42-2 Cross Section 1135
- 42-3 Nuclear Fission; Nuclear Reactors 1136
- 42-4 Nuclear Fusion 1141
- 42-5 Passage of Radiation Through Matter; Radiation Damage 1146
- 42-6 Measurement of Radiation—Dosimetry 1147
- \*42-7 Radiation Therapy 1150
- \*42-8 Tracers in Research and Medicine 1151
- \*42-9 Imaging by Tomography: CAT Scans and Emission Tomography 1153
- \*42-10 Nuclear Magnetic Resonance (NMR); Magnetic Resonance Imaging (MRI) 1156

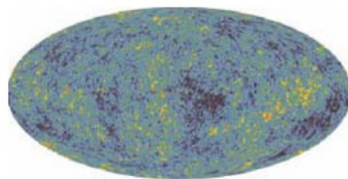
SUMMARY 1159 QUESTIONS 1159  
PROBLEMS 1160 GENERAL PROBLEMS 1162



## 43 ELEMENTARY PARTICLES 1164

- 43-1 High-Energy Particles and Accelerators 1165
- 43-2 Beginnings of Elementary Particle Physics—Particle Exchange 1171
- 43-3 Particles and Antiparticles 1174
- 43-4 Particle Interactions and Conservation Laws 1175
- 43-5 Neutrinos—Recent Results 1177
- 43-6 Particle Classification 1178
- 43-7 Particle Stability and Resonances 1180
- 43-8 Strangeness? Charm? Towards a New Model 1181
- 43-9 Quarks 1182
- 43-10 The Standard Model: QCD and Electroweak Theory 1184
- 43-11 Grand Unified Theories 1187
- 43-12 Strings and Supersymmetry 1189

SUMMARY 1189 QUESTIONS 1190  
PROBLEMS 1190 GENERAL PROBLEMS 1191



## 44 ASTROPHYSICS AND COSMOLOGY 1193

- 44-1 Stars and Galaxies 1194
- 44-2 Stellar Evolution: Nucleosynthesis, and the Birth and Death of Stars 1197
- 44-3 Distance Measurements 1203
- 44-4 General Relativity: Gravity and the Curvature of Space 1205
- 44-5 The Expanding Universe: Redshift and Hubble's Law 1209
- 44-6 The Big Bang and the Cosmic Microwave Background 1213
- 44-7 The Standard Cosmological Model: Early History of the Universe 1216
- 44-8 Inflation 1219
- 44-9 Dark Matter and Dark Energy 1221
- 44-10 Large-Scale Structure of the Universe 1224
- 44-11 Finally ... 1224

SUMMARY 1225 QUESTIONS 1226  
PROBLEMS 1226 GENERAL PROBLEMS 1227

## APPENDICES

- A MATHEMATICAL FORMULAS A-1
- B DERIVATIVES AND INTEGRALS A-6
- C MORE ON DIMENSIONAL ANALYSIS A-8
- D GRAVITATIONAL FORCE DUE TO A SPHERICAL MASS DISTRIBUTION A-9
- E DIFFERENTIAL FORM OF MAXWELL'S EQUATIONS A-12
- F SELECTED ISOTOPES A-14
- ANSWERS TO ODD-NUMBERED PROBLEMS A-18
- INDEX A-47
- PHOTO CREDITS A-72



# APPLICATIONS (SELECTED)

## Chapter 1

The 8000-m peaks	8
Estimating volume of a lake	10
Height by triangulation	11
Radius of the Earth	11
Heartbeats in a lifetime	12
Particulate pollution (Pr30)	15
Global positioning satellites (Pr39)	16
Lung capacity (Pr65)	17

## Chapter 2

Airport runway design	29
Automobile air bags	31
Braking distances	32
CD error correction (Pr10)	44
CD playing time (Pr13)	45
Golfing uphill or down (Pr79)	48
Rapid transit (Pr83)	49

## Chapter 3

Kicked football	66, 69
Ball sports (Problems)	77, 81, 82
Extreme sports (Pr41)	77

## Chapter 4

Rocket acceleration	90
What force accelerates a car?	90
How we walk	90
Elevator and counterweight	99
Mechanical advantage of pulley	100
Bear sling (Q24)	104
High-speed elevators (Pr19)	105
Mountain climbing (Pr31, 82, 83)	106, 110
City planning, cars on hills (Pr71)	109
Bicyclists (Pr72, 73)	109
“Doomsday” asteroid (Pr84)	110

## Chapter 5

Push or pull a sled?	116
Centrifugation	122
Not skidding on a curve	126–7
Banked highways	127
Simulated gravity (Q18, Pr48)	131, 134
“Rotor-ride” (Pr82)	136

## Chapter 6

Oil/mineral exploration	144, 420
Artificial Earth satellites	146
Geosynchronous satellites	147
Weightlessness	148
Free fall in athletics	149
Planet discovery, extrasolar planets	152
Black holes	156
Asteroids (Pr44, 78)	159, 162
Navstar GPS (Pr58)	160
Black hole, galaxy center (Pr61, 64)	160, 161
Tides (Pr75)	162

## Chapter 7

Car stopping distance of $v^2$	174
Lever (Pr6)	177
Spiderman (Pr54)	179
Bicycling on hills, gears (Pr85)	181
Child safety in car (Pr87)	181
Rock climber’s rope (Pr90)	182

## Chapter 8

Downhill ski runs	183
Roller coaster	191, 198
Pole vault	192–3
Toy dart gun	193

Escape velocity from Earth or Moon	201
Stair climbing power	202
Power needs of car	202–3
Cardiac treadmill (Pr104)	213

## Chapter 9

Tennis serve	216
Rocket propulsion	219, 236–8
Rifle recoil	220
Karate blow	221
Billiards/bowling	223, 228
Nuclear collisions	225, 228
Ballistic pendulum	226
Conveyor belt	237
Gravitational slingshot (Pr105)	246
Crashworthiness (Pr109)	247
Asteroids, planets (Pr110, 112, 113)	247

## Chapter 10

Hard drive and bit speed	253
Wrench/tire iron	256
Flywheel energy	266, 281
Yo-yo	271
Car braking forces	272–3
Bicycle odometer calibration (Q1)	275
Tightrope walker (Q11)	275
Triceps muscle and throwing (Pr38, 39)	278
CD speed (Pr84)	281
Bicycle gears (Pr89)	281

## Chapter 11

Rotating skaters, divers	284, 286, 309
Neutron star collapse	287
Auto wheel balancing	296
Top and gyroscope	299–300
Coriolis effect	301–2
Hurricanes	302
SUV possible rollover (Pr67)	308
Triple axel jump (Pr79)	309
Bat’s “sweet spot” (Pr82)	310

## Chapter 12

Tragic collapse	311, 323
Lever’s mechanical advantage	313
Cantilever	315
Biceps muscle force	315
Human balance with loads	318
Trusses and bridges	324–6, 335
Architecture: arches and domes	327–8
Forces on vertebrae (Pr87)	337

## Chapter 13

Lifting water	345, 348
Hydraulic lift, brakes	346
Pressure gauges	346–7
Hydrometer	351
Helium balloon lift	352, 368
Blood flow	353, 357, 361
Airplane wings, lift	356
Sailing against the wind	357
Baseball curve	357
Blood to the brain, TIA	357
Blood flow and heart disease	359
Surface tension, capillarity	359–60
Walking on water	360
Pumps and the heart	361
Reynolds number (Pr69)	366

## Chapter 14

Car shock absorbers	383
Resonance damage	386

## Chapter 15

Echolocation by animals	400
Earthquake waves	401, 403, 416

## Chapter 16

Distance from lightning	425
Autofocus camera	426
Wide range of human hearing	427–8, 431
Loudspeaker response	428
Stringed instruments	432–3
Wind instruments	433–6
Tuning with beats	439
Doppler blood flow meter	442, 453
Sonar: sonic boom	444
Ultrasound medical imaging	445–6
Motion sensor (Pr5)	448

## Chapter 17

Hot air balloon	454
Expansion joints, highways	456, 460, 463
Gas tank overflow	462
Life under ice	462
Cold and hot tire pressure	468
Molecules in a breath	469
Thermostat (Q10)	471
Scuba/snorkeling (Pr38, 47, 82, 85)	473, 475

## Chapter 18

Chemical reactions, temperature dependence	481
Superfluidity	483
Evaporation cools	484, 505
Humidity, weather	485–6
Chromatography	490
Pressure cooker (Pr35)	493

## Chapter 19

Working off the calories	498
Cold floors	516
Heat loss through windows	516
How clothes insulate	516–7
$R$ -values for thermal insulation	517
Convective house heating	517
Human radiative heat loss	518
Room comfort and metabolism	519
Radiation from Sun	519
Medical thermography	519
Astronomy—size of a star	520
Thermos bottle (Q30)	521
Weather, air parcel, adiabatic lapse rate (Pr56)	525

## Chapter 20

Steam engine	530
Internal combustion engine	531, 535–6
Car efficiency	532
Refrigerators, air conditioners	537–8
Heat pump	538
Biological evolution, development	545
Thermal pollution, global warming	549–51
Energy resources	550
Diesel engine (Pr7)	553

## Chapter 21

Static electricity	560, 589 (Pr78)
Photocopiers	569, 582–3
Electric shielding, safety	577
DNA structure and replication	581–2
Biological cells: electric forces and kinetic theory	581–2, 617
Laser & inkjet printers	583





# Preface

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I was motivated from the beginning to write a textbook different from others that present physics as a sequence of facts, like a Sears catalog: “here are the facts and you better learn them.” Instead of that approach in which topics are begun formally and dogmatically, I have sought to begin each topic with concrete observations and experiences students can relate to: start with specifics and only then go to the great generalizations and the more formal aspects of a topic, showing *why* we believe what we believe. This approach reflects how science is actually practiced.

## Why a Fourth Edition?

---

Two recent trends in physics textbooks are disturbing: (1) their revision cycles have become short—they are being revised every 3 or 4 years; (2) the books are getting larger, some over 1500 pages. I don’t see how either trend can be of benefit to students. My response: (1) It has been 8 years since the previous edition of this book. (2) This book makes use of physics education research, although it avoids the detail a Professor may need to say in class but in a book shuts down the reader. And this book still remains among the shortest.

This new edition introduces some important new pedagogic tools. It contains new physics (such as in cosmology) and many new appealing applications (list on previous page). Pages and page breaks have been carefully formatted to make the physics easier to follow: no turning a page in the middle of a derivation or Example. Great efforts were made to make the book attractive so students will want to *read* it.

Some of the new features are listed below.

## What’s New

---

**Chapter-Opening Questions:** Each Chapter begins with a multiple-choice question, whose responses include common misconceptions. Students are asked to answer before starting the Chapter, to get them involved in the material and to get any preconceived notions out on the table. The issues reappear later in the Chapter, usually as Exercises, after the material has been covered. The Chapter-Opening Questions also show students the power and usefulness of Physics.

**APPROACH paragraph in worked-out numerical Examples:** A short introductory paragraph before the Solution, outlining an approach and the steps we can take to get started. Brief NOTES after the Solution may remark on the Solution, may give an alternate approach, or mention an application.

**Step-by-Step Examples:** After many Problem Solving Strategies (more than 20 in the book), the next Example is done step-by-step following precisely the steps just seen.

**Exercises** within the text, after an Example or derivation, give students a chance to see if they have understood enough to answer a simple question or do a simple calculation. Many are multiple choice.

**Greater clarity:** No topic, no paragraph in this book was overlooked in the search to improve the clarity and conciseness of the presentation. Phrases and sentences that may slow down the principal argument have been eliminated: keep to the essentials at first, give the elaborations later.

$\vec{F}$ ,  $\vec{v}$ ,  $\vec{B}$

**Vector notation, arrows:** The symbols for vector quantities in the text and Figures now have a tiny arrow over them, so they are similar to what we write by hand.

**Cosmological Revolution:** With generous help from top experts in the field, readers have the latest results.

**Page layout:** more than in the previous edition, serious attention has been paid to how each page is formatted. Examples and all important derivations and arguments are on facing pages. Students then don't have to turn back and forth. Throughout, readers see, on two facing pages, an important slice of physics.

**New Applications:** LCDs, digital cameras and electronic sensors (CCD, CMOS), electric hazards, GFCIs, photocopiers, inkjet and laser printers, metal detectors, underwater vision, curve balls, airplane wings, DNA, how we actually *see* images. (Turn back a page to see a longer list.)

**Examples modified:** more math steps are spelled out, and many new Examples added. About 10% of all Examples are Estimation Examples.

**This Book is Shorter** than other complete full-service books at this level. Shorter explanations are easier to understand and more likely to be read.

## Content and Organizational Changes

- **Rotational Motion:** Chapters 10 and 11 have been reorganized. All of angular momentum is now in Chapter 11.
- **First law of thermodynamics,** in Chapter 19, has been rewritten and extended. The full form is given:  $\Delta K + \Delta U + \Delta E_{\text{int}} = Q - W$ , where internal energy is  $E_{\text{int}}$ , and  $U$  is potential energy; the form  $Q - W$  is kept so that  $dW = P dV$ .
- Kinematics and Dynamics of Circular Motion are now treated together in Chapter 5.
- Work and Energy, Chapters 7 and 8, have been carefully revised.
- Work done by friction is discussed now with energy conservation (energy terms due to friction).
- Chapters on Inductance and AC Circuits have been combined into one: Chapter 30.
- Graphical Analysis and Numerical Integration is a new optional Section 2–9. Problems requiring a computer or graphing calculator are found at the end of most Chapters.
- Length of an object is a script  $\ell$  rather than normal  $l$ , which looks like 1 or I (moment of inertia, current), as in  $F = I\ell B$ . Capital  $L$  is for angular momentum, latent heat, inductance, dimensions of length  $[L]$ .
- Newton's law of gravitation remains in Chapter 6. Why? Because the  $1/r^2$  law is too important to relegate to a late chapter that might not be covered at all late in the semester; furthermore, it is one of the basic forces in nature. In Chapter 8 we can treat real gravitational potential energy and have a fine instance of using  $U = -\int \vec{F} \cdot d\vec{\ell}$ .
- New Appendices include the differential form of Maxwell's equations and more on dimensional analysis.
- Problem Solving Strategies are found on pages 30, 58, 64, 96, 102, 125, 166, 198, 229, 261, 314, 504, 551, 571, 685, 716, 740, 763, 849, 871, and 913.

## Organization

Some instructors may find that this book contains more material than can be covered in their courses. The text offers great flexibility. Sections marked with a star \* are considered optional. These contain slightly more advanced physics material, or material not usually covered in typical courses and/or interesting applications; they contain no material needed in later Chapters (except perhaps in later optional Sections). For a brief course, all optional material could be dropped as well as major parts of Chapters 1, 13, 16, 26, 30, and 35, and selected parts of Chapters 9, 12, 19, 20, 33, and the modern physics Chapters. Topics not covered in class can be a valuable resource for later study by students. Indeed, this text can serve as a useful reference for years because of its wide range of coverage.

## Versions of this Book

**Complete version:** 44 Chapters including 9 Chapters of modern physics.

**Classic version:** 37 Chapters including one each on relativity and quantum theory.

**3 Volume version:** Available separately or packaged together (Vols. 1 & 2 or all 3 Volumes):

**Volume 1:** Chapters 1–20 on mechanics, including fluids, oscillations, waves, plus heat and thermodynamics.

**Volume 2:** Chapters 21–35 on electricity and magnetism, plus light and optics.

**Volume 3:** Chapters 36–44 on modern physics: relativity, quantum theory, atomic physics, condensed matter, nuclear physics, elementary particles, cosmology and astrophysics.

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---

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He has taught a wide range of undergraduate courses, traditional as well as innovative ones, and continues to update his textbooks meticulously, seeking ways to better provide an understanding of physics for students.

Doug's favorite spare-time activity is the outdoors, especially climbing peaks (here on a dolomite summit, Italy). He says climbing peaks is like learning physics: it takes effort and the rewards are great.



### Online Supplements (partial list)

#### **MasteringPhysics™ (www.masteringphysics.com)**

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# To Students

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## HOW TO STUDY

1. Read the Chapter. Learn new vocabulary and notation. Try to respond to questions and exercises as they occur.
2. Attend all class meetings. Listen. Take notes, especially about aspects you do not remember seeing in the book. Ask questions (everyone else wants to, but maybe you will have the courage). You will get more out of class if you read the Chapter first.
3. Read the Chapter again, paying attention to details. Follow derivations and worked-out Examples. Absorb their logic. Answer Exercises and as many of the end of Chapter Questions as you can.
4. Solve 10 to 20 end of Chapter Problems (or more), especially those assigned. In doing Problems you find out what you learned and what you didn't. Discuss them with other students. Problem solving is one of the great learning tools. Don't just look for a formula—it won't cut it.

## NOTES ON THE FORMAT AND PROBLEM SOLVING

1. Sections marked with a star (\*) are considered **optional**. They can be omitted without interrupting the main flow of topics. No later material depends on them except possibly later starred Sections. They may be fun to read, though.
2. The customary **conventions** are used: symbols for quantities (such as  $m$  for mass) are italicized, whereas units (such as m for meter) are not italicized. Symbols for vectors are shown in boldface with a small arrow above:  $\vec{F}$ .
3. Few equations are valid in all situations. Where practical, the **limitations** of important equations are stated in square brackets next to the equation. The equations that represent the great laws of physics are displayed with a tan background, as are a few other indispensable equations.
4. At the end of each Chapter is a set of **Problems** which are ranked as Level I, II, or III, according to estimated difficulty. Level I Problems are easiest, Level II are standard Problems, and Level III are “challenge problems.” These ranked Problems are arranged by Section, but Problems for a given Section may depend on earlier material too. There follows a group of General Problems, which are not arranged by Section nor ranked as to difficulty. Problems that relate to optional Sections are starred (\*). Most Chapters have 1 or 2 Computer/Numerical Problems at the end, requiring a computer or graphing calculator. Answers to odd-numbered Problems are given at the end of the book.
5. Being able to solve **Problems** is a crucial part of learning physics, and provides a powerful means for understanding the concepts and principles. This book contains many aids to problem solving: (a) worked-out **Examples** and their solutions in the text, which should be studied as an integral part of the text; (b) some of the worked-out Examples are **Estimation Examples**, which show how rough or approximate results can be obtained even if the given data are sparse (see Section 1–6); (c) special **Problem Solving Strategies** placed throughout the text to suggest a step-by-step approach to problem solving for a particular topic—but remember that the basics remain the same; most of these “Strategies” are followed by an Example that is solved by explicitly following the suggested steps; (d) special problem-solving Sections; (e) “Problem Solving” marginal notes which refer to hints within the text for solving Problems; (f) **Exercises** within the text that you should work out immediately, and then check your response against the answer given at the bottom of the last page of that Chapter; (g) the Problems themselves at the end of each Chapter (point 4 above).
6. **Conceptual Examples** pose a question which hopefully starts you to think and come up with a response. Give yourself a little time to come up with your own response before reading the Response given.
7. **Math** review, plus some additional topics, are found in Appendices. Useful data, conversion factors, and math formulas are found inside the front and back covers.



## USE OF COLOR

### Vectors

A general vector	
resultant vector (sum) is slightly thicker	
components of any vector are dashed	
Displacement ( $\vec{D}$ , $\vec{r}$ )	
Velocity ( $\vec{v}$ )	
Acceleration ( $\vec{a}$ )	
Force ( $\vec{F}$ )	
Force on second or third object in same figure	
Momentum ( $\vec{p}$ or $m\vec{v}$ )	
Angular momentum ( $\vec{L}$ )	
Angular velocity ( $\vec{\omega}$ )	
Torque ( $\vec{\tau}$ )	
Electric field ( $\vec{E}$ )	
Magnetic field ( $\vec{B}$ )	

### Electricity and magnetism

Electric field lines	
Equipotential lines	
Magnetic field lines	
Electric charge (+)	or
Electric charge (-)	or

### Electric circuit symbols

Wire, with switch S	
Resistor	
Capacitor	
Inductor	
Battery	
Ground	

### Optics

Light rays	
Object	
Real image (dashed)	
Virtual image (dashed and paler)	

### Other

Energy level (atom, etc.)	
Measurement lines	
Path of a moving object	
Direction of motion or current	