

Contents

CHAPTER 1. ATOMS IN MOTION

- 1-1 Introduction 1-1
- 1-2 Matter is made of atoms 1-2
- 1-3 Atomic processes 1-5
- 1-4 Chemical reactions 1-6

CHAPTER 2. BASIC PHYSICS

- 2-1 Introduction 2-1
- 2-2 Physics before 1920 2-3
- 2-3 Quantum physics 2-6
- 2-4 Nuclei and particles 2-8

CHAPTER 3. THE RELATION OF PHYSICS TO OTHER SCIENCES

- 3-1 Introduction 3-1
- 3-2 Chemistry 3-1
- 3-3 Biology 3-2
- 3-4 Astronomy 3-6
- 3-5 Geology 3-7
- 3-6 Psychology 3-8
- 3-7 How did it get that way? 3-9

CHAPTER 4. CONSERVATION OF ENERGY

- 4-1 What is energy? 4-1
- 4-2 Gravitational potential energy 4-2
- 4-3 Kinetic energy 4-5
- 4-4 Other forms of energy 4-6

CHAPTER 5. TIME AND DISTANCE

- 5-1 Motion 5-1
- 5-2 Time 5-1
- 5-3 Short times 5-2
- 5-4 Long times 5-3
- 5-5 Units and standards of time 5-5
- 5-6 Large distances 5-5
- 5-7 Short distances 5-8

CHAPTER 6. PROBABILITY

- 6-1 Chance and likelihood 6-1
- 6-2 Fluctuations 6-3
- 6-3 The random walk 6-5
- 6-4 A probability distribution 6-7
- 6-5 The uncertainty principle 6-10

CHAPTER 7. THE THEORY OF GRAVITATION

- 7-1 Planetary motions 7-1
- 7-2 Kepler's laws 7-1
- 7-3 Development of dynamics 7-2
- 7-4 Newton's law of gravitation 7-3
- 7-5 Universal gravitation 7-5
- 7-6 Cavendish's experiment 7-9
- 7-7 What is gravity? 7-9
- 7-8 Gravity and relativity 7-11

CHAPTER 8. MOTION

- 8-1 Description of motion 8-1
- 8-2 Speed 8-2
- 8-3 Speed as a derivative 8-5
- 8-4 Distance as an integral 8-7
- 8-5 Acceleration 8-8

CHAPTER 9. NEWTON'S LAWS OF DYNAMICS

- 9-1 Momentum and force 9-1
- 9-2 Speed and velocity 9-2
- 9-3 Components of velocity, acceleration, and force 9-3
- 9-4 What is the force? 9-3
- 9-5 Meaning of the dynamical equations 9-4
- 9-6 Numerical solution of the equations 9-5
- 9-7 Planetary motions 9-6

CHAPTER 10. CONSERVATION OF MOMENTUM

- 10-1 Newton's Third Law 10-1
- 10-2 Conservation of momentum 10-2
- 10-3 Momentum *is* conserved! 10-5
- 10-4 Momentum and energy 10-7
- 10-5 Relativistic momentum 10-8

CHAPTER 11. VECTORS

- 11-1 Symmetry in physics 11-1
- 11-2 Translations 11-1
- 11-3 Rotations 11-3
- 11-4 Vectors 11-5
- 11-5 Vector algebra 11-6
- 11-6 Newton's laws in vector notation 11-7
- 11-7 Scalar product of vectors 11-8

CHAPTER 12. CHARACTERISTICS OF FORCE

- 12-1 What is a force? 12-1
- 12-2 Friction 12-3
- 12-3 Molecular forces 12-6
- 12-4 Fundamental forces. Fields 12-7
- 12-5 Pseudo forces 12-10
- 12-6 Nuclear forces 12-12

CHAPTER 13. WORK AND POTENTIAL ENERGY (A)

- 13-1 Energy of a falling body 13-1
- 13-2 Work done by gravity 13-3
- 13-3 Summation of energy 13-6
- 13-4 Gravitational field of large objects 13-8

CHAPTER 14. WORK AND POTENTIAL ENERGY (conclusion)

- 14-1 Work 14-1
- 14-2 Constrained motion 14-3
- 14-3 Conservative forces 14-3
- 14-4 Nonconservative forces 14-6
- 14-5 Potentials and fields 14-7

CHAPTER 15. THE SPECIAL THEORY OF RELATIVITY

- 15-1 The principle of relativity 15-1
- 15-2 The Lorentz transformation 15-3
- 15-3 The Michelson-Morley experiment 15-3
- 15-4 Transformation of time 15-5
- 15-5 The Lorentz contraction 15-7
- 15-6 Simultaneity 15-7
- 15-7 Four-vectors 15-8
- 15-8 Relativistic dynamics 15-9
- 15-9 Equivalence of mass and energy 15-10

CHAPTER 16. RELATIVISTIC ENERGY AND MOMENTUM

- 16-1 Relativity and the philosophers 16-1
- 16-2 The twin paradox 16-3
- 16-3 Transformation of velocities 16-4
- 16-4 Relativistic mass 16-6
- 16-5 Relativistic energy 16-8

CHAPTER 17. SPACE-TIME

- 17-1 The geometry of space-time 17-1
- 17-2 Space-time intervals 17-2
- 17-3 Past, present, and future 17-4
- 17-4 More about four-vectors 17-5
- 17-5 Four-vector algebra 17-7

CHAPTER 18. ROTATION IN TWO DIMENSIONS

- 18-1 The center of mass 18-1
- 18-2 Rotation of a rigid body 18-2
- 18-3 Angular momentum 18-5
- 18-4 Conservation of angular momentum 18-6

CHAPTER 19. CENTER OF MASS; MOMENT OF INERTIA

- 19-1 Properties of the center of mass 19-1
- 19-2 Locating the center of mass 19-4
- 19-3 Finding the moment of inertia 19-5
- 19-4 Rotational kinetic energy 19-7

CHAPTER 20. ROTATION IN SPACE

- 20-1 Torques in three dimensions 20-1
- 20-2 The rotation equations using cross products 20-4
- 20-3 The gyroscope 20-5
- 20-4 Angular momentum of a solid body 20-8

CHAPTER 21. THE HARMONIC OSCILLATOR

- 21-1 Linear differential equations 21-1
- 21-2 The harmonic oscillator 21-1
- 21-3 Harmonic motion and circular motion 21-4
- 21-4 Initial conditions 21-4
- 21-5 Forced oscillations 21-5

CHAPTER 22. ALGEBRA

- 22-1 Addition and multiplication 22-1
- 22-2 The inverse operations 22-2
- 22-3 Abstraction and generalization 22-3
- 22-4 Approximating irrational numbers 22-4
- 22-5 Complex numbers 22-7
- 22-6 Imaginary exponents 22-9

CHAPTER 23. RESONANCE

- 23-1 Complex numbers and harmonic motion 23-1
- 23-2 The forced oscillator with damping 23-3

- 23-3 Electrical resonance 23-5
- 23-4 Resonance in nature 23-7

CHAPTER 24. TRANSIENTS

- 24-1 The energy of an oscillator 24-1
- 24-2 Damped oscillations 24-2
- 24-3 Electrical transients 24-5

CHAPTER 25. LINEAR SYSTEMS AND REVIEW

- 25-1 Linear differential equations 25-1
- 25-2 Superposition of solutions 25-2
- 25-3 Oscillations in linear systems 25-5
- 25-4 Analogs in physics 25-6
- 25-5 Series and parallel impedances 25-8

CHAPTER 26. OPTICS: THE PRINCIPLE OF LEAST TIME

- 26-1 Light 26-1
- 26-2 Reflection and refraction 26-2
- 26-3 Fermat's principle of least time 26-3
- 26-4 Applications of Fermat's principle 26-5
- 26-5 A more precise statement of Fermat's principle 26-7
- 26-6 How it works 26-8

CHAPTER 27. GEOMETRICAL OPTICS

- 27-1 Introduction 27-1
- 27-2 The focal length of a spherical surface 27-1
- 27-3 The focal length of a lens 27-4
- 27-4 Magnification 27-5
- 27-5 Compound lenses 27-6
- 27-6 Aberrations 27-7
- 27-7 Resolving power 27-7

CHAPTER 28. ELECTROMAGNETIC RADIATION

- 28-1 Electromagnetism 28-1
- 28-2 Radiation 28-3
- 28-3 The dipole radiator 28-5
- 28-4 Interference 28-6

CHAPTER 29. INTERFERENCE

- 29-1 Electromagnetic waves 29-1
- 29-2 Energy of radiation 29-2
- 29-3 Sinusoidal waves 29-2
- 29-4 Two dipole radiators 29-3
- 29-5 The mathematics of interference 29-5

CHAPTER 30. DIFFRACTION

- 30-1 The resultant amplitude due to n equal oscillators 30-1
- 30-2 The diffraction grating 30-3
- 30-3 Resolving power of a grating 30-5
- 30-4 The parabolic antenna 30-6
- 30-5 Colored films; crystals 30-7
- 30-6 Diffraction by opaque screens 30-8
- 30-7 The field of a plane of oscillating charges 30-10

CHAPTER 31. THE ORIGIN OF THE REFRACTIVE INDEX

- 31-1 The index of refraction 31-1
- 31-2 The field due to the material 31-4
- 31-3 Dispersion 31-6
- 31-4 Absorption 31-8
- 31-5 The energy carried by an electric wave 31-9
- 31-6 Diffraction of light by a screen 31-10

CHAPTER 32. RADIATION DAMPING. LIGHT SCATTERING

- 32-1 Radiation resistance 32-1
- 32-2 The rate of radiation of energy 32-2
- 32-3 Radiation damping 32-3
- 32-4 Independent sources 32-5
- 32-5 Scattering of light 32-6

CHAPTER 33. POLARIZATION

- 33-1 The electric vector of light 33-1
- 33-2 Polarization of scattered light 33-3
- 33-3 Birefringence 33-3
- 33-4 Polarizers 33-5
- 33-5 Optical activity 33-6
- 33-6 The intensity of reflected light 33-7
- 33-7 Anomalous refraction 33-9

CHAPTER 34. RELATIVISTIC EFFECTS IN RADIATION

- 34-1 Moving sources 34-1
- 34-2 Finding the "apparent" motion 34-2
- 34-3 Synchrotron radiation 34-3
- 34-4 Cosmic synchrotron radiation 34-6
- 34-5 Bremsstrahlung 34-6
- 34-6 The Doppler effect 34-7
- 34-7 The ω, k four-vector 34-9
- 34-8 Aberration 34-10
- 34-9 The momentum of light 34-10

CHAPTER 35. COLOR VISION

- 35-1 The human eye 35-1
- 35-2 Color depends on intensity 35-2
- 35-3 Measuring the color sensation 35-3
- 35-4 The chromaticity diagram 35-6
- 35-5 The mechanism of color vision 35-7
- 35-6 Physiochemistry of color vision 35-9

CHAPTER 36. MECHANISMS OF SEEING

- 36-1 The sensation of color 36-1
- 36-2 The physiology of the eye 36-3
- 36-3 The rod cells 36-6
- 36-4 The compound (insect) eye 36-6
- 36-5 Other eyes 36-9
- 36-6 Neurology of vision 36-9

CHAPTER 37. QUANTUM BEHAVIOR

- 37-1 Atomic mechanics 37-1
- 37-2 An experiment with bullets 37-2
- 37-3 An experiment with waves 37-3
- 37-4 An experiment with electrons 37-4
- 37-5 The interference of electron waves 37-5
- 37-6 Watching the electrons 37-7
- 37-7 First principles of quantum mechanics 37-10
- 37-8 The uncertainty principle 37-11

CHAPTER 38. THE RELATION OF WAVE AND PARTICLE VIEWPOINTS

- 38-1 Probability wave amplitudes 38-1
- 38-2 Measurement of position and momentum 38-2
- 38-3 Crystal diffraction 38-4
- 38-4 The size of an atom 38-5

- 38-5 Energy levels 38-7
- 38-6 Philosophical implications 38-8

CHAPTER 39. THE KINETIC THEORY OF GASES

- 39-1 Properties of matter 39-1
- 39-2 The pressure of a gas 39-2
- 39-3 Compressibility of radiation 39-6
- 39-4 Temperature and kinetic energy 39-6
- 39-5 The ideal gas law 39-10

CHAPTER 40. THE PRINCIPLES OF STATISTICAL MECHANICS

- 40-1 The exponential atmosphere 40-1
- 40-2 The Boltzmann law 40-2
- 40-3 Evaporation of a liquid 40-3
- 40-4 The distribution of molecular speeds 40-4
- 40-5 The specific heats of gases 40-7
- 40-6 The failure of classical physics 40-8

CHAPTER 41. THE BROWNIAN MOVEMENT

- 41-1 Equipartition of energy 41-1
- 41-2 Thermal equilibrium of radiation 41-3
- 41-3 Equipartition and the quantum oscillator 41-6
- 41-4 The random walk 41-8

CHAPTER 42. APPLICATIONS OF KINETIC THEORY

- 42-1 Evaporation 42-1
- 42-2 Thermionic emission 42-4
- 42-3 Thermal ionization 42-5
- 42-4 Chemical kinetics 42-7
- 42-5 Einstein's laws of radiation 42-8

CHAPTER 43. DIFFUSION

- 43-1 Collisions between molecules 43-1
- 43-2 The mean free path 43-3
- 43-3 The drift speed 43-4
- 43-4 Ionic conductivity 43-6
- 43-5 Molecular diffusion 43-7
- 43-6 Thermal conductivity 43-9

CHAPTER 44. THE LAWS OF THERMODYNAMICS

- 44-1 Heat engines; the first law 44-1
- 44-2 The second law 44-3
- 44-3 Reversible engines 44-4
- 44-4 The efficiency of an ideal engine 44-7
- 44-5 The thermodynamic temperature 44-9
- 44-6 Entropy 44-10

CHAPTER 45. ILLUSTRATIONS OF THERMODYNAMICS

- 45-1 Internal energy 45-1
- 45-2 Applications 45-4
- 45-3 The Clausius-Clapeyron equation 45-6

CHAPTER 46. RATCHET AND PAWL

- 46-1 How a ratchet works 46-1
- 46-2 The ratchet as an engine 46-2
- 46-3 Reversibility in mechanics 46-4
- 46-4 Irreversibility 46-5
- 46-5 Order and entropy 46-7

CHAPTER 47. SOUND. THE WAVE EQUATION

- 47-1 Waves 47-1
- 47-2 The propagation of sound 47-3
- 47-3 The wave equation 47-4
- 47-4 Solutions of the wave equation 47-6
- 47-5 The speed of sound 47-7

CHAPTER 48. BEATS

- 48-1 Adding two waves 48-1
- 48-2 Beat notes and modulation 48-3
- 48-3 Side bands 48-4
- 48-4 Localized wave trains 48-5
- 48-5 Probability amplitudes for particles 48-7
- 48-6 Waves in three dimensions 48-9
- 48-7 Normal modes 48-10

CHAPTER 49. MODES

- 49-1 The reflection of waves 49-1
- 49-2 Confined waves, with natural frequencies 49-2
- 49-3 Modes in two dimensions 49-3
- 49-4 Coupled pendulums 49-6
- 49-5 Linear systems 49-7

INDEX

CHAPTER 50. HARMONICS

- 50-1 Musical tones 50-1
- 50-2 The Fourier series 50-2
- 50-3 Quality and consonance 50-3
- 50-4 The Fourier coefficients 50-5
- 50-5 The energy theorem 50-7
- 50-6 Nonlinear responses 50-8

CHAPTER 51. WAVES

- 51-1 Bow waves 51-1
- 51-2 Shock waves 51-2
- 51-3 Waves in solids 51-4
- 51-4 Surface waves 51-7

CHAPTER 52. SYMMETRY IN PHYSICAL LAWS

- 52-1 Symmetry operations 52-1
- 52-2 Symmetry in space and time 52-1
- 52-3 Symmetry and conservation laws 52-3
- 52-4 Mirror reflections 52-4
- 52-5 Polar and axial vectors 52-6
- 52-6 Which hand is right? 52-8
- 52-7 Parity is not conserved! 52-8
- 52-8 Antimatter 52-10
- 52-9 Broken symmetries 52-11

