530 HAL Pt.1

Contents

1 PHYSICAL MEASUREMENT 1

1–1 Measurement 1
1–2 Physical Quantities, Standards, and Units 2
1–3 Frames of Reference 3
1–4 Length 4
1–5 Time 5
1–6 Systems of Units 10

2 VECTORS 13

2–1 Vectors and Scalars 13
2–2 Addition of Vectors, Geometrical Method 14
2–3 Resolution and Addition of Vectors, Analytical Method 16
2–4 Multiplication of Vectors 20
2–5 Physical Significance of Vector Quantities 23

3 MOTION IN ONE DIMENSION 27

3–1 Mechanics 27
3–2 Particle Kinematics 27
3–3 Average Velocity 28
3–4 Instantaneous Velocity 29
3–5 Average Acceleration 33
3–6 Instantaneous Acceleration 33
3–7 Rectilinear Motion with Constant Acceleration 34
3–8 Dimensional Consistency 37
3–9 Freely Falling Bodies 39
3–10 Equations of Motion in Free Fall 41

4 MOTION IN A PLANE 47

4–1 Displacement and Velocity in Curved Motion 47
4–2 Motion in a Plane with Constant Acceleration 49
4–3 Projectile Motion 50
4–4 Uniform Circular Motion 55
4–5 Tangential Acceleration in Circular Motion 58
4–6 Relative Velocity and Acceleration 59

5 PARTICLE DYNAMICS—I 66

5–1 Particle Dynamics 66
5–2 Newton's First Law of Motion 66
5–3 Force 68
5–4 Concept of Mass: Newton's Second Law of Motion 69
5–5 Newton's Third Law of Motion 72
5–6 Mass Standards, Systems of Mechanical Units 75
5–7 Weight and Mass 78
5–8 A Static Procedure for Measuring Forces 79
5–9 Some Application of Newton's Laws of Motion 80
5–10 Critique of Newton's Laws of Motion 88

6 PARTICLE DYNAMICS—II 95

6–1 Introduction 95
6–2 Frictional Forces 95
6–3 Centripetal and Centrifugal Forces 101
6–4 The Limitations of Newtonian Mechanics 105

7 WORK AND ENERGY 111

7–1 Introduction 111
7–2 Work Done by a Constant Force 112
7–3 Work Done by a Variable Force 116
7–4 Power 121
7–5 Kinetic Energy 122
7–6 Significance of the Work-Energy Theorem 125

8 THE CONSERVATION OF ENERGY 128

8–1 Introduction 128
8–2 Conservative and Nonconservative Forces 128
8–3 Potential Energy 131
8–4 One-Dimensional Conservative Systems 133
8–5 The Complete Solution of the Problem for One-Dimensional Forces Depending on Position Only 137
8–6 Two- and Three-Dimensional Conservative Systems 141

8–7 Nonconservative Forces 142
8–8 The Conservation of Energy 144
8–9 Mass and Energy 145

9 CONSERVATION OF LINEAR MOMENTUM 153

9–1 Center of Mass 153
9–2 Motion of the Center of Mass 158
9–3 Linear Momentum of a Particle 161
9–4 Linear Momentum of a System of Particles 162
9–5 Conservation of Linear Momentum 164
9–6 Some Applications of the Momentum Principle 165

10 COLLISIONS 177

10–1 Introduction 177
10–2 Impulse and Momentum 177
10–3 Collision Phenomena 179
10–4 Collisions in One Dimension 182
10–5 The "True" Measure of a Force 189
10–6 Collisions in Two and Three Dimensions 190
10–7 Collision Cross Section 192

11 ROTATIONAL KINEMATICS 202

11–1 Rotational Motion 202
11–2 Rotational Kinematics 204
11–3 Rotational Quantities as Vectors 206
11–4 Rotation with Constant Angular Acceleration 208
11–5 Relation between Linear and Angular Kinematics of a Particle in Circular Motion 210

12 ROTATIONAL DYNAMICS 216

12–1 Rotational Variables 216
12–2 Torque, or Moment of a Force 218
12–3 Kinetic Energy of Rotation and Rotational Inertia 224
12–4 Rotational Dynamics of a Rigid Body 229
12–5 The Combined Translational and Rotational Motion of a Rigid Body 235

13 THE CONSERVATION OF ANGULAR MOMENTUM 245

13–1 Introduction 245
13–2 Angular Momentum of a Particle 245
13–3 Angular Momentum of a System of Particles 247
13–4 Conservation of Angular Momentum 250

13–5 Some Other Aspects of the Conservation of Angular Momentum 257

14 STATICS OF RIGID BODIES 262

14–1 Mechanical Equilibrium 262
14–2 The Conditions for Mechanical Equilibrium of a Rigid Body 263
14–3 Center of Gravity 265
14–4 Examples of Static Equilibrium 268
14–5 Stable, Unstable, and Neutral Equilibrium of Rigid Bodies in a Gravitational Field 275

15 OSCILLATIONS 282

15–1 Harmonic Motion 282
15–2 The Simple Harmonic Oscillator 283
15–3 Simple Harmonic Motion 286
15–4 Energy Considerations in Simple Harmonic Motion 291
15–5 Applications of Simple Harmonic Motion 295
15–6 Relation between Simple Harmonic Motion and Uniform Circular Motion 302
15–7 Combinations of Harmonic Motions 306
15–8 Damped Harmonic Motion 308
15–9 Forced Oscillations and Resonance 310

16 GRAVITATION 317

16–1 Historical Introduction 317
16–2 The Law of Universal Gravitation 321
16–3 The Constant of Universal Gravitation, G 322
16–4 Inertial and Gravitational Mass 325
16–5 Variations in Acceleration Due to Gravity 327
16–6 Gravitational Effect of a Spherical Distribution of Mass 330
16–7 The Motion of Planets and Satellites 334
16–8 The Gravitational Field 339
16–9 Gravitational Potential Energy 341
16–10 Energy Considerations in Planetary Motion 345
16–11 The Earth as a Frame of Reference 347
16–12 Inertial Guidance 347

17 FLUID STATICS 355

17–1 Fluids 355
17–2 Pressure and Density 355
17–3 The Variation of Pressure in a Fluid at Rest 357

17–4 Pascal's Principle and Archimedes' Principle 362
17–5 Measurement of Pressure 364

18 FLUID DYNAMICS 371

18–1 General Concepts of Fluid Flow 371
18–2 Streamline Flow 373
18–3 The Equation of Continuity 374
18–4 Bernoulli's Equation 376
18–5 Applications of Bernoulli's Equation and the Equation of Continuity 379
18–6 Other Conservation Laws in Fluid Mechanics 383
18–7 Fields of Flow 383

19 WAVES IN ELASTIC MEDIA 392

19–1 Mechanical Waves 392
19–2 Types of Waves 393
19–3 Traveling Waves 396
19–4 The Superposition Principle 400
19–5 Wave Velocity 402
19–6 Power and Intensity in Wave Motion 405
19–7 Interference of Waves 407
19–8 Complex Waves 410
19–9 Standing Waves 412
19–10 Resonance 416

20 SOUND WAVES 422

20–1 Audible, Ultrasonic, and Infrasonic Waves 422
20–2 Propagation and Speed of Longitudinal Waves 423
20–3 Traveling Longitudinal Waves 426
20–4 Standing Longitudinal Waves 429
20–5 Vibrating Systems and Sources of Sound 430
20–6 Beats 437
20–7 The Doppler Effect 439

21 TEMPERATURE 448

21–1 Macroscopic and Microscopic Descriptions 448
21–2 Thermal Equilibrium—The Zeroth Law of Thermodynamics 449
21–3 Measurement of Temperature 450
21–4 The Gas Thermometer 453
21–5 Ideal Gas Temperature 454
21–6 The Celsius and Fahrenheit Scales 456
21–7 The International Temperature Scale 457
21–8 Temperature Expansion 458

22 HEAT AND THE FIRST LAW OF THERMODYNAMICS 466

22–1 Heat, a Form of Energy 466
22–2 Quantity of Heat and Specific Heat 468
22–3 Heat Conduction 471
22–4 The Mechanical Equivalent of Heat 474
22–5 Heat and Work 475
22–6 The First Law of Thermodynamics 480
22–7 Some Applications of the First Law of Thermodynamics 481

23 KINETIC THEORY OF GASES—I 489

23–1 Historical Introduction 489
23–2 Equation of State of an Ideal Gas 490
23–3 Kinetic Theory Model of a Gas 492
23–4 Kinetic Calculation of the Pressure 494
23–5 Kinetic Interpretation of Temperature 498
23–6 Intermolecular Forces 500
23–7 Specific Heats of an Ideal Gas 502
23–8 Equipartition of Energy 506

24 KINETIC THEORY OF GASES—II 513

24–1 Mean Free Path 513
24–2 Distribution of Molecular Speeds 516
24–3 Experimental Confirmation of the Maxwellian Distribution 520
24–4 The Brownian Movement 522
24–5 The van der Waals Equation of a Gas 525

25 ENTROPY AND THE SECOND LAW OF THERMODYNAMICS 532

25–1 Introduction 532
25–2 Reversible and Irreversible Processes 532
25–3 The Carnot Cycle 534
25–4 The Second Law of Thermodynamics 538
25–5 The Efficiency of Engines 540
25–6 The Absolute Thermodynamic Temperature Scale 543
25–7 Entropy 545
25–8 Entropy and Disorder 550

APPENDICES *1*

ANSWERS TO PROBLEMS *29*

INDEX *33*