

# Contents

<b>Preface</b> . . . . .	<b>v</b>
<b>Chapter 1. Vector Algebra</b> . . . . .	<b>1</b>
1-1. Scalars and Vectors . . . . .	1
1-2. Geometrical Representations of Vectors . . . . .	2
1-3. Equality of Vectors . . . . .	3
1-4. Product of a Vector and Scalar . . . . .	3
1-5. Addition and Subtraction of Vectors . . . . .	3
1-6. Unit Vectors . . . . .	5
1-7. Components of a Vector . . . . .	6
1-8. Addition of Vectors by the Method of Components . . . . .	7
Problems . . . . .	9
<b>Chapter 2. Newton's Laws; Concurrent Force Systems; Equilibrium of a Particle</b> . . . . .	<b>12</b>
2-1. Newton's Laws . . . . .	12
2-2. Discussion of Newton's Laws . . . . .	13
2-3. Statics and the Equations of Equilibrium of a Particle . . . . .	15
2-4. Simple Structures . . . . .	17
2-5. Friction . . . . .	21
2-6. Procedure of Solving Problems in Statics of a Particle . . . . .	24
Problems . . . . .	25
<b>Chapter 3. Vector Products</b> . . . . .	<b>29</b>
3-1. Introduction . . . . .	29
3-2. Scalar Product . . . . .	29
3-3. Vector Product . . . . .	33
3-4. Physical Significance of Scalar Product; Work; Line Integrals . . . . .	36
3-5. Physical Significance of Vector Product; Moment . . . . .	39
3-6. Moment of a Vector . . . . .	43
3-7. Velocity Due to Rotation; Angular-velocity Vector . . . . .	45
3-8. Triple Vector Products . . . . .	46
Problems . . . . .	49

<b>Chapter 4. Statics of Systems of Particles and of Rigid Bodies . . . . .</b>	<b>52</b>
4-1. Equilibrium of a System of Particles . . . . .	52
4-2. Constraint of a Rigid Body in Space . . . . .	54
4-3. Equilibrium of a Rigid Body in Space . . . . .	56
4-4. Procedures of Solving Problems in Statics of Rigid Bodies . . . . .	57
4-5. Examples of Statics of Rigid Bodies . . . . .	60
4-6. Couple . . . . .	65
4-7. Equipollence of Force Systems in Space . . . . .	66
4-8. Reduction of Force Systems; Wrench . . . . .	68
Problems. . . . .	72
<b>Chapter 5. More Applications of Statics . . . . .</b>	<b>77</b>
5-1. Systems of Parallel Forces. . . . .	77
5-2. Center of Gravity; Center of Mass; Centroid . . . . .	79
5-3. Pressure in a Static Fluid . . . . .	85
5-4. Forces Due to Fluid Static Pressure: Plane Surfaces . . . . .	89
5-5. Forces Due to Fluid Static Pressure: Curved Surfaces. . . . .	94
5-6. Buoyant Force; Stability of Floating Bodies . . . . .	96
Problems. . . . .	99
<b>Chapter 6. Derivatives of Vectors; Kinematics of a Particle . . . . .</b>	<b>104</b>
6-1. Derivative of a Vector . . . . .	104
6-2. Derivative of Sums and Products. . . . .	105
6-3. Curves in Space; Principal Normals and Binormals . . . . .	107
6-4. Displacement, Velocity, and Acceleration of a Particle . . . . .	110
6-5. Kinematics of a Particle: Rectangular Coordinates . . . . .	111
6-6. Kinematics of a Particle: Tangential and Normal Components . . . . .	113
6-7. Kinematics of a Particle: Cylindrical Coordinates . . . . .	114
6-8. Kinematics of a Particle: Spherical Coordinates . . . . .	116
Problems. . . . .	119
<b>Chapter 7. Kinematics of a Rigid Body; Relative Motions . . . . .</b>	<b>123</b>
7-1. Displacements of a Rigid Body . . . . .	123
7-2. Kinematics of a Rigid Body . . . . .	126
7-3. The Eulerian Angles . . . . .	131
7-4. Motion of a Point of a Rigid Body . . . . .	133
7-5. Four-bar Linkages . . . . .	136
7-6. Rate of Change of a Vector in a Moving Frame . . . . .	139
7-7. Motion Referred to a Moving Coordinate System . . . . .	141
Problems. . . . .	147
<b>Chapter 8. Dynamics of a Particle . . . . .</b>	<b>153</b>
8-1. General Considerations. . . . .	153
8-2. Simple Harmonic Motion . . . . .	157
8-3. Motion in a Resisting Medium . . . . .	161
8-4. Central Forces; Planetary and Satellite Motions . . . . .	162
8-5. Example: Satellite Orbits . . . . .	167
8-6. Work and Kinetic Energy . . . . .	170
8-7. Potential Energy . . . . .	171
8-8. Examples of Conservative Force Fields; Gravitation . . . . .	173
8-9. Example: The Simple Pendulum . . . . .	176

8-10. Motion of a Particle in a Moving Coordinate System . . . . .	181
Problems. . . . .	184
<b>Chapter 9. Vibrating Systems . . . . .</b>	<b>188</b>
9-1. Generalized Coordinates and Degrees of Freedom . . . . .	188
9-2. Vibrations . . . . .	189
9-3. Differential Equations of One-degree-of-freedom Vibrating Systems. . . . .	191
9-4. Free Vibrations without Damping . . . . .	193
9-5. Free Vibrations with Damping . . . . .	197
9-6. The Case of Negligible Mass; The Differential Equation $\tau \dot{x} + x = 0$ . . . . .	200
9-7. Forced Vibrations without Damping. . . . .	202
9-8. Forced Vibrations with Viscous Damping . . . . .	207
9-9. Vibration Isolation . . . . .	210
9-10. Torsional Vibration. . . . .	213
9-11. Vibrations with Nonperiodic Forces . . . . .	214
9-12. More Complicated Vibrating Systems; Nonlinear Vibrations . . . . .	215
Problems. . . . .	219
<b>Chapter 10. Dynamics of Systems of Particles . . . . .</b>	<b>223</b>
10-1. Motion of the Mass Center . . . . .	223
10-2. Impulse and Momentum of a System of Particles . . . . .	224
10-3. Angular Momentum of a System of Particles . . . . .	227
10-4. Systems with Variable Mass; Rocket and Jet Propulsion . . . . .	233
10-5. Kinetic Energy of a System of Particles. . . . .	236
10-6. The Virial Theorem . . . . .	238
10-7. Elementary Kinetic Theory of Gases. . . . .	238
10-8. Viscosity of a Gas . . . . .	241
10-9. Statistical Mechanics . . . . .	244
Problems. . . . .	245
<b>Chapter 11. Moments and Products of Inertia . . . . .</b>	<b>249</b>
11-1. Introduction and Definitions . . . . .	249
11-2. Translation of Coordinate Axes . . . . .	252
11-3. Moments and Products of Inertia of Some Simple Bodies. . . . .	253
11-4. Rotation of Coordinate Axes . . . . .	256
11-5. Orthogonal Transformations . . . . .	258
11-6. Moments and Products of Inertia with Respect to Rotated Coordinates . . . . .	260
11-7. Cauchy's Inertia Ellipsoid. . . . .	262
11-8. Principal Moments of Inertia and Principal Axes . . . . .	263
11-9. Plane Rotation of Axes; Mohr's-circle Representation. . . . .	268
Problems. . . . .	274
<b>Chapter 12. Dynamics of Rigid Bodies. . . . .</b>	<b>277</b>
12-1. Euler's Equations of Motion of a Rigid Body . . . . .	277
12-2. Work-and-energy Equation of a Rigid Body . . . . .	282
12-3. Example: Motion of an Air-borne Vehicle . . . . .	286
12-4. Stability of the Rotational Motion of a Rigid Body . . . . .	290
12-5. Types of Motion of a Rigid Body . . . . .	293
12-6. Rigid Body under No Forces; Poincot's Representation . . . . .	294
12-7. Free Motion of a Symmetrical Gyroscope . . . . .	298
12-8. Symmetrical Gyroscope under External Moments . . . . .	303
12-9. The Gyrocompass . . . . .	307

xii     *Contents*

12-10. Rigid Body in Translation . . . . .	310
12-11. Rotation about a Fixed Axis; Dynamic Balancing . . . . .	311
12-12. Plane Motion of a Rigid Body . . . . .	316
Problems. . . . .	319
<b>Chapter 13. Lagrange's Equations . . . . .</b>	<b>326</b>
13-1. Introduction . . . . .	326
13-2. Virtual Displacements; Stability of Equilibrium . . . . .	328
13-3. Lagrange's Equation for a Particle . . . . .	333
13-4. Lagrange's Equation for a System of Particles . . . . .	338
13-5. Small Free Vibrations of Coupled Systems . . . . .	340
13-6. Small Vibrations of Two-degree-of-freedom Systems . . . . .	342
13-7. Free and Forced Vibrations of $n$ -degree-of-freedom Systems; Normal Coordinates . . . . .	346
Problems. . . . .	356
<b>Appendix A. Properties of Plane Geometric Shapes . . . . .</b>	<b>A1</b>
<b>Appendix B. Properties of Solid Homogeneous Bodies . . . . .</b>	<b>A5</b>
<b>Answers to Selected Problems . . . . .</b>	<b>A9</b>
<b>Index. . . . .</b>	<b>A17</b>