

Contents

1 Mathematical Notation	11
2 Rigid Body Kinematics	19
2.1 Generalized coordinates for the angular orientation of a rigid body	19
2.1.1 Euler angles	19
2.1.2 Bryant angles	21
2.1.3 Euler parameters	23
2.2 The notion of angular velocity	25
2.3 Relationships between the angular velocity of a body and generalized coordinates describing the angular orientation of the body	29
2.3.1 Direction cosines	29
2.3.2 Euler angles	30
2.3.3 Bryant angles	30
2.3.4 Euler parameters	31
3 Basic Principles of Rigid Body Dynamics	33
3.1 Kinetic energy	33
3.2 Angular momentum	34
3.3 Properties of moments and products of inertia	35
3.3.1 Transition to another reference point without change of the reference base	35
3.3.2 Transition to another reference base without change of the reference point	36
3.3.3 Principal axes and principal moments of inertia	36
3.3.4 Invariants and inequalities for moments and products of inertia	37
3.4 The law of moment of momentum	39
3.5 D'Alembert's principle applied to a rigid body	42
4 Classical Problems of Rigid Body Mechanics	44
4.1 The unsymmetric torque-free rigid body	44
4.1.1 Polhodes and permanent rotations	45
4.1.2 Poinsot's geometric interpretation of the motion	46
4.1.3 The solution of Euler's equations of motion	48
4.1.4 The solution of the kinematic differential equations	50
4.2 The symmetric torque-free rigid body	53
4.3 The self-excited, symmetric rigid body	55
4.4 The symmetric heavy top	56
4.5 The symmetric heavy body in a cardan suspension	63
4.6 The gyrostat. General considerations	66

4.7	The torque-free gyrostat	70
4.7.1	Polhodes and permanent rotations	71
4.7.2	The solution of the dynamic equations of motion	73
5	General Multi-Body Systems	80
5.1	Introductory remarks	80
5.2	Equations of motion for systems with tree structure	84
5.2.1	The mathematical description of the interconnection structure .	84
5.2.2	Systems with ball-and-socket joints. One body is coupled to an external body whose motion is prescribed	90
5.2.3	The special case of plane motions	101
5.2.4	Systems with ball-and-socket joints without coupling to an external body whose motion is prescribed	107
5.2.5	The special case of a multi-body satellite in a circular orbit . .	115
5.2.6	Systems with ball-and-socket, universal and pin joints . . .	124
5.2.7	Programming instructions	133
5.2.8	Systems with arbitrary holonomic constraints in the hinges .	145
5.2.9	Internal forces and torques in the hinges of a system with arbitrary holonomic constraints	166
5.3	Multi-body systems with closed chains and with arbitrary constraints .	167
5.3.1	The mathematical description of the interconnection structure. A generalization of Section 5.2.1	169
5.3.2	Equations of motion	172
5.4	Concluding remarks	189
6	Impact Problems in Holonomic Multi-Body Systems	191
6.1	Basic assumptions	191
6.2	Instantaneous velocity increments	193
6.3	An analogy to the law of Maxwell and Betti	200
6.4	Internal impulses and impulse couples in hinges	206
Answers to Problems	215	
Literature References	221	
Index	223	