

Contents

Preface	xi
Acknowledgments	xv

CHAPTER 1 Dynamics of point masses	1
1.1 Introduction	1
1.2 Vectors	2
1.3 Kinematics	10
1.4 Mass, force and Newton's law of gravitation.....	15
1.5 Newton's law of motion.....	19
1.6 Time derivatives of moving vectors.....	24
1.7 Relative motion	29
1.8 Numerical integration.....	38
1.8.1 Runge-Kutta methods.....	42
1.8.2 Heun's Predictor-Corrector method.....	48
1.8.3 Runge-Kutta with variable step size.....	50
Problems	54
List of Key Terms	59
CHAPTER 2 The two-body problem	61
2.1 Introduction	61
2.2 Equations of motion in an inertial frame	62
2.3 Equations of relative motion	70
2.4 Angular momentum and the orbit formulas.....	74
2.5 The energy law	82
2.6 Circular orbits ($e = 0$)	83
2.7 Elliptical orbits ($0 < e < 1$).....	89
2.8 Parabolic trajectories ($e = 1$).....	100
2.9 Hyperbolic trajectories ($e > 1$).....	104
2.10 Perifocal frame	113
2.11 The lagrange coefficients	117
2.12 Restricted three-body problem.....	129
2.12.1 Lagrange points	133
2.12.2 Jacobi constant.....	139
Problems	146
List of Key Terms	152

CHAPTER 3	Orbital position as a function of time	155
3.1	Introduction	155
3.2	Time since periaxis	155
3.3	Circular orbits ($e = 0$)	156
3.4	Elliptical orbits ($e < 1$)	157
3.5	Parabolic trajectories ($e = 1$)	172
3.6	Hyperbolic trajectories ($e > 1$)	174
3.7	Universal variables	182
Problems	194	
List of Key Terms	197	
CHAPTER 4	Orbits in three dimensions	199
4.1	Introduction	199
4.2	Geocentric right ascension-declination frame	200
4.3	State vector and the geocentric equatorial frame	203
4.4	Orbital elements and the state vector	208
4.5	Coordinate transformation	216
4.6	Transformation between geocentric equatorial and perifocal frames	229
4.7	Effects of the Earth's oblateness	233
4.8	Ground tracks	244
Problems	249	
List of Key Terms	254	
CHAPTER 5	Preliminary orbit determination	255
5.1	Introduction	255
5.2	Gibbs method of orbit determination from three position vectors	256
5.3	Lambert's problem	263
5.4	Sidereal time	275
5.5	Topocentric coordinate system	280
5.6	Topocentric equatorial coordinate system	283
5.7	Topocentric horizon coordinate system	284
5.8	Orbit determination from angle and range measurements	289
5.9	Angles only preliminary orbit determination	297
5.10	Gauss method of preliminary orbit determination	297
Problems	312	
List of Key Terms	317	
CHAPTER 6	Orbital maneuvers	319
6.1	Introduction	319
6.2	Impulsive maneuvers	320
6.3	Hohmann transfer	321
6.4	Bi-elliptic Hohmann transfer	328
6.5	Phasing maneuvers	332
6.6	Non-Hohmann transfers with a common apse line	338
6.7	Apse line rotation	343
6.8	Chase maneuvers	350

6.9	Plane change maneuvers	355
6.10	Nonimpulsive orbital maneuvers.....	368
	Problems	374
	List of Key Terms	390
CHAPTER 7 Relative motion and rendezvous.....		391
7.1	Introduction	391
7.2	Relative motion in orbit.....	392
7.3	Linearization of the equations of relative motion in orbit	400
7.4	Clohessy-Wiltshire equations.....	407
7.5	Two-impulse rendezvous maneuvers.....	411
7.6	Relative motion in close-proximity circular orbits	419
	Problems	421
	List of Key Terms	427
CHAPTER 8 Interplanetary trajectories		429
8.1	Introduction	429
8.2	Interplanetary Hohmann transfers	430
8.3	Rendezvous Opportunities	432
8.4	Sphere of influence.....	437
8.5	Method of patched conics	441
8.6	Planetary departure.....	442
8.7	Sensitivity analysis.....	448
8.8	Planetary rendezvous	451
8.9	Planetary flyby	458
8.10	Planetary ephemeris	470
8.11	Non-Hohmann interplanetary trajectories	475
	Problems	482
	List of Key Terms	483
CHAPTER 9 Rigid-body dynamics.....		485
9.1	Introduction	485
9.2	Kinematics	486
9.3	Equations of translational motion	495
9.4	Equations of rotational motion.....	497
9.5	Moments of inertia.....	501
	9.5.1 Parallel axis theorem	517
9.6	Euler's equations	524
9.7	Kinetic energy	530
9.8	The spinning top.....	533
9.9	Euler angles	538
9.10	Yaw, pitch and roll angles	549
9.11	Quaternions	552
	Problems	561
	List of Key Terms	571

CHAPTER 10 Satellite attitude dynamics	573
10.1 Introduction	573
10.2 Torque-free motion	574
10.3 Stability of torque-free motion	584
10.4 Dual-spin spacecraft	589
10.5 Nutation damper	593
10.6 Coning maneuver	601
10.7 Attitude control thrusters	605
10.8 Yo-yo despin mechanism	608
10.8.1 Radial release	613
10.9 Gyroscopic attitude control	615
10.10 Gravity gradient stabilization	631
Problems	644
List of Key Terms	653
CHAPTER 11 Rocket vehicle dynamics	655
11.1 Introduction	655
11.2 Equations of motion	656
11.3 The thrust equation	658
11.4 Rocket performance	660
11.5 Restricted staging in field-free space	667
11.6 Optimal staging	678
11.6.1 Lagrange multiplier	678
Problems	686
List of Key Terms	688
Appendix A Physical data	689
Appendix B A road map	691
Appendix C Numerical intergration of the <i>n</i>-body equations of motion	693
Appendix D MATLAB® algorithms	701
Appendix E Gravitational potential energy of a sphere	703
References	707
Index	709