## **CONTENTS**

Preface				
H	istori	cal Background	VII	
1.	TH	E SIMPLIFIED TWO-BODY PROBLEM	1	
		Position, Velocity and Acceleration	1	
	1.2	The Attraction Force	4	
	1.3	Shape of Path	5	
	1.4	The Eccentricity Vector	6	
		Suggested Reading	7	
		Problems	8	
2.	KE	PLER ORBITS	11	
	2.1	Angular Momentum	12	
	2.2	Period	12	
	2.3	Vis-Viva Integral	14	
	2.4	Velocities	17	
		Potential Energy	21	
	2.6	Total Energy	23	
	2.7	Kepler Laws	24	
	2.8	Time of Flight	25	
	2.9	The Anomalies	26	
	2.10	A Universal Variable	27	
	2.11	Kepler Equations	28	
	2.12	Lambert Equations	29	
	2.13	Orbital Elements	31	
	2.14	Tethered Satellites	33	
		Suggested Reading	34	
		Problems	34	
_				
3.		BIT INSERTION	39	
		Insertion into Periapsis (or Apoapsis)	39	
	3.2	Insertion into an Arbitrary Point of the Orbit	43	
		Problems	48	
4.	TR/	ANSFER	51	
	4.1	Single Impulse	51	
	4.2	Coplanar Transfer	52	
	4.3	Change of Orbital Plane	55	
	4.4	Transfer to a Prescribed Target Orbit	56	
	4.5	Hohmann Transfer	58	
	4.6	Hohmann Transfer Onto Larger Circular Orbit	59	
	4.7	Energy Increase Due to Velocity Kick	60	
	4.8	Fuel Requirements	61	



	4.9	Energy Increase for Hohmann Transfer	61
	4.10	Mass Losses Considered	62
	4.11	Transfer Time for Hohmann Transfer	64
	4.12	Several Impulses, Continuous Impulse	64
	4.13	Launch Windows	65
		Suggested Reading	66
		Problems	66
5.	THI	E GRAVITATIONAL POTENTIAL	71
	5.1	Approximate Potential Surrounding a Body of Arbitrary Shape	71
	5.2	Potential Surrounding a Body of Arbitrary Shape	74
	5.3	Potential Surrounding a Body of Revolution	7 <b>7</b>
	5.4	Perturbation Force in Gravitational Potential	79
	5.5	Flattening	82
	5.6	Inertia Moments	83
	5.7	The Earth	84
		Suggested Reading	85
		Problems	86
6.	VA	RIATION OF GEOMETRIC ORBITAL ELEMENTS	89
	6.1	Perturbation Force and Velocity Change	90
	6.2	Rate of Change of Magnitude of Semi-Major Axis	90
	6.3	Rate of Change of Eccentricity	91
	6.4	Rate of Change of Right Ascension of Ascending Node	92
	6.5	Rate of Change of Orientation of Line of Apsides	94
	6.6	Rate of Change of Inclination	97
		Problems	98
7.	SEC	CULAR VARIATIONS OF THE ORBITAL ELEMENTS	101
	7.1	Precession of the Orbital Plane	101
	7.2	Rotation of the Line of Apsides	103
	7.3	Major Axis, Eccentricity, Inclination	105
		Problems	106
8.	OR	BITAL PERIODS	107
	8.1	Absolute Period	107
		Nodal Period	109
	8.3	Apsidal Period	110
		Problems	111
9.		HER PERTURBATIONS	113
	9.1	Air Resistance	113
		Circular Orbit	114
		Upper Limit of the Atmosphere	117
	9.4	Elliptic Orbit	118

9.5	The Solar Wind	120
9.6	Satellite Temperature	121
	Suggested Reading	122
	Problems	122
10. SA	TELLITES FROM INFINITY	125
10.1	Hyperbolic Orbits	125
10.2	The Collision Radius	128
	Primary Master and Secondary Master	129
10.4	Energy Gain	132
10.5	Influence Sphere	132
10.6	The Spacecraft as Satellite of the Secondary Master	133
10.7	Perturbation Acceleration	134
10.8	The Spacecraft as a Satellite of the Primary Master	135
10.9	The Tisserand Equation	135
	Suggested Reading	138
	Problems	138
	E GENERAL TWO-BODY PROBLEM	141
	Orbits	143
	The Earth-Moon System	145
	The Sun - (Earth + Moon) System	145
	Problem	146
12. SA	TELLITES IN THE EARTH-MOON SYSTEM	147
12.1	The Moon	147
12.2	A Point Satellite in the Earth-Moon System	148
12.3	Satellites Within the Lunar Orbital Plane	153
10.4		
12.4	An Energy Consideration	154
	An Energy Consideration Hill's Curves	
12.5		154
12.5	Hill's Curves	154 155
12.5 12.6	Hill's Curves Libration Points	154 155 156
12.5 12.6	Hill's Curves Libration Points Suggested Reading Problems	154 155 156 158
12.5 12.6 13. TII	Hill's Curves Libration Points Suggested Reading Problems	154 155 156 158 158 160
12.5 12.6 13. TII	Hill's Curves   Libration Points   Suggested Reading   Problems   OAL FORCES   Suggested Reading	154 155 156 158 158 160 163
12.5 12.6 13. TII	Hill's Curves Libration Points Suggested Reading Problems	154 155 156 158 158 160
12.5 12.6 13. TII	Hill's Curves   Libration Points   Suggested Reading   Problems   OAL FORCES   Suggested Reading	154 155 156 158 158 160 163
12.5 12.6 13. TII Append	Hill's Curves   Libration Points   Suggested Reading   Problems   OAL FORCES   Suggested Reading   Problems   Problems	154 155 156 158 158 160 163 163
12.5 12.6 13. TIL Append Append	Hill's Curves   Libration Points   Suggested Reading   Problems   OAL FORCES   Suggested Reading   Problems   ix A: Space Data	154 155 156 158 158 160 163 163 163
12.5 12.6 13. TII Append Append	Hill's Curves   Libration Points   Suggested Reading   Problems   DAL FORCES   Suggested Reading   Problems   ix A: Space Data   ix B: Engineering Data	154 155 156 158 158 160 163 163 163 165 174
12.5 12.6 13. TII Append Append Append	Hill's Curves   Libration Points   Suggested Reading   Problems   OAL FORCES   Suggested Reading   Problems   ix A: Space Data   ix B: Engineering Data   ix C: Nomenclature	154 155 156 158 158 160 163 163 163 165 174 177