

Contents

Preface	I
List of Important Symbols	III
List of Abbreviations and Acronyms Used	IX
Introduction	1
1 Definition, Historical Evolution of the Subject	4
1.1 Definition of the Subject and Its Division	4
1.2 Outline of the Historical Evolution of the Research into the Figure of the Earth in the Pre-satellite Era	5
1.3 Historical Evolution of Space Geodesy and Space Geodynamics	11
2 Systems of Coordinates	17
2.1 Geocentric Systems	17
2.2 Geodetic Systems of Reference	20
2.3 Topocentric Systems	22
2.4 The Problem of Realizing an Inertial Coordinate System	23
3 Equations of Motion of a Satellite and Their Solution	33
3.1 Equations of Motion in the Inertial Coordinate System and in the System Fixed with the Earth's Body	33
3.2 Equations of Motion of a Satellite in an Ideal Gravitational Field of the Earth and Their Solution	38
3.3 Perturbations Due to Third Bodies	47
3.4 Effects of Non-gravitational Origin	51
3.4.1 Atmospheric Effects	51
3.4.2 Effect of Atmospheric Lift	55
3.4.3 Effect of the Atmosphere on Kepler's Orbital Elements	56
3.4.4 Effect of Solar Radiation	56
3.4.5 Shadow Function	58
3.4.6 Effect of Radiation	60
3.4.7 Variation in Kepler's Elements Due To Solar Radiation	63
4 Gravitational and Gravity Potential at Points of the Earth's Surface and in Outer Space	65
4.1 Introductory Remarks	65
4.2 Gravitational Potential of a Perfectly Rigid Earth	66
4.3 Physical Meaning of Stokes Parameters of the Earth	69
4.4 Variations of the Gravitational Potential of the Earth's Body with Time	74
4.5 Potential of the Centrifugal Force and Its Variations	79
4.6 Time Variable Gravity Potential	89
5 Motion of an Artificial Satellite in the Gravitational Field of the Earth, Moon and Sun	93
5.1 Perturbing Function	93

5.2	An Outline of the Solution of Perturbed Motion	94
5.3	Variations in the Orbital Elements of the Satellite Due to Stokes Parameters - Classification of Perturbations by Type	96
6	Methods and Achievements of Satellite Geodesy	102
6.1	Introductory Remarks	102
6.2	Determination of the Stokes Parameters of the Earth from Orbital Dynamics of Artificial Satellites	103
6.3	Geopotential Scale Factor	108
6.4	Expansion of the Geocentric Radius-Vector of the Basic Equipotential Surface	112
6.5	Geoid Heights	121
6.6	Geometric Characteristics of External Equipotential Surfaces Derived from Satellite Observations	128
6.6.1	Gauss' Curvature of Equipotential Surfaces	128
6.6.2	Directions of Normals, Deflections of the Vertical	136
6.7	Fundamental Geodetic Parameters of the Earth Derived from Satellite Observations	146
6.8	Gravity in Outer Space Derived from Satellite Observations	159
6.9	Gravity Potential and Gravity Acceleration on the Surface of the Geocentric Tri-axial Earth Ellipsoid	167
6.10	Mean Value of Gravity Acceleration on the Geoid and Its Equator	172
6.11	Parameters of the Normal Gravity Field of the Earth Derived from Satellite Observations	176
6.12	Determining Gravity Anomalies from Satellite Observations	189
6.13	Parameters of the Geocentric Ellipsoid of Inertia Derived from Satellite Observations	192
6.14	Resonance Methods	200
6.15	Individual Stokes Parameters Determined from Lumped Coefficients	208
6.16	The Use of Geostationary Satellites in Physical Satellite Geodesy	213
6.17	Satellite-to-Satellite Tracking	216
6.18	Gradiometry	219
6.19	Satellite Altimetry	224
6.20	Models of the Geopotential	226
6.21	GPS - Theoretical Aspects	235
6.21.1	The NAVSTAR System	235
6.21.2	Transmitted and Received Signals	238
6.21.3	Measurement of Pseudoranges, Satellite Radio Ranging	240
6.21.4	Phase Measurements	241
6.21.5	Interferometry	243
6.21.6	Doppler Observations	245
6.21.7	Corrections to Actual Measurements	246
6.21.8	Principles of Processing Observations	248
7	Principles of Space Geodynamics	249
7.1	Problems and Methods of Space Geodynamics	249
7.2	Very Long Baseline Interferometry	250
7.3	Lunar Laser Ranging	256
7.4	Determining Time Variations in the Vector of the Earth's Rotation	260
7.4.1	Introduction	260
7.4.2	Polar Motion	266
7.4.2.1	Rotation of the Earth as a Rigid Body	267
7.4.2.2	Liouville's Equation	273
7.4.2.3	Positions of the Axes of the Ellipsoid of Inertia for a Deformed Earth	277
7.4.2.4	Relation Between the Components of the Tensor of Inertia and the Components of the Vector of Rotation	277
7.4.2.5	Gravitational Effect of the Sun and the Moon on Variations in the Spin Angular Momentum and Principal Moment of Inertia	282

7.4.2.6	Excitation Function Generated by Tidal Deformations	284
7.4.2.7	Excitation Function Generated by Atmosphere Dynamics	285
7.4.2.8	Resultant Equations	286
7.4.3	Precession and Nutation	288
7.4.3.1	Euler's Kinematic Equations	289
7.4.3.2	Precession and Nutation. Motion of the Angular Momentum Vector	290
7.4.3.3	Precession and Nutation of the Rotational Axis and of the Axis of the Ellipsoid of Inertia	293
7.4.3.4	Motion of the Rotation Vector	296
7.4.4	Deformations of the Earth Due to Variations in Its Rotation	299
7.4.5	Effect of the Deformations of the Earth Due to Rotation on Satellite Motion	309
7.5	Determination of Tidal Deformations of the Earth	311
7.5.1	The Tidal Deforming Potential	311
7.5.2	Tidal Variations of Gravity and Plumb-line; Tilts of the Earth's Crust	316
7.5.3	Harmonic Expansion of the Tide-forming Potential. Tidal Waves	319
7.5.4	The Earth's Tidal Deformations Due to Planets	330
7.5.5	Torque of Tidal Forces	333
7.5.6	Determination of the Earth's Tidal Parameters by Space Methods	335
7.6	Relative Motions Close to the Earth's Surface	340
7.6.1	Equations of Motion in the Coordinate System Fixed with the Earth	340
7.6.2	Phenomena Close to the Earth's Surface, Generated by Coriolis' Force	344
7.6.3	Deflection of a Free-falling Body from the Vertical Due to the Earth's Rotation (Coriolis' Force)	345
7.6.4	Foucault's Pendulum	349
7.7	Determination of Motions of the Earth's Crust	352
7.7.1	Wegener's Theory of Continental Drift	352
7.7.2	Contemporary Models of Movements of Lithospheric Plates	354
7.8	Long-term Global Variations in the Earth's Gravity Field	359
7.8.1	Sources of the Long-term Global Variations	359
7.8.2	Diminishing of the Second Zonal Stokes Parameter and Its Effect on Global Geodynamic Phenomena	359
7.8.3	Diminishing of the Earth's Angular Rotation Velocity Due to Tidal Friction	371
7.8.4	Secular Polar Motion	385
7.8.5	The Expanding Earth Hypothesis in the Light of Contemporary Space Dynamics Data	403
7.9	Geodynamic Origin of the Fourth Zonal Stokes Parameter	406
7.10	Primary Geodetic Parameters with Regard to Geodynamics	411
7.10.1	Choosing Primary Geodetic Parameters with Regard to Long-term Geodynamic Phenomena	411
7.10.2	Derived Geodetic Parameters	415
7.10.3	Altimetric Determination of the Geopotential Scale Factor with Regard to Ocean and Sea Surface Topography	425
	Supplements	431
S1	Legendre Polynomials and Associated Legendre Functions	431
S2	Some Relations Between Legendre Polynomials and Associated Legendre Functions	433
S3	Required in Deriving the Fundamental Relations of Space Geodesy	437
	Full Spherical Harmonics Normalization Factor	437
	References	441
	Subject Index	455