

Contents

1	Introduction	1
1.1	Objectives and Classifications of Geodesy	1
1.1.1	Objectives of Geodesy	1
1.1.2	Classifications of Geodesy	2
1.2	Applications of Geodesy	3
1.2.1	Applications of Geodesy in Topographic Mapping, Engineering Construction, and Transportation	3
1.2.2	Applications of Geodesy in Space Technology	5
1.2.3	Applications of Geodesy in Geoscience Research	6
1.2.4	Applications of Geodesy in Resource Development, Environmental Monitoring, and Protection	8
1.2.5	Applications of Geodesy in Disaster Prevention, Resistance, and Mitigation	10
1.3	Brief History and Trends in the Development of Geodesy	12
1.3.1	Brief History of Geodesy	12
1.3.2	Trends in the Development of Geodesy	16
	Review and Study Questions	19
2	Geodetic Data Collection Techniques	21
2.1	Terrestrial Triangulation	21
2.1.1	Angle Measurement	21
2.1.2	Distance Measurement	27
2.1.3	Astronomical Measurement	30
2.2	Height Measurement	33
2.2.1	Leveling	33
2.2.2	Trigonometric Leveling	35
2.3	Space Geodetic Surveying	37
2.3.1	GPS Surveying	37
2.3.2	Satellite Laser Ranging	43
2.3.3	Very Long Baseline Interferometry	47
2.3.4	Satellite Altimetry	53

2.4	Gravimetry	58
2.4.1	Absolute Gravimetry	58
2.4.2	Relative Gravimetry	62
2.4.3	Airborne Gravimetry	62
2.4.4	Satellite Gravimetry	66
	Review and Study Questions	68
3	Geodetic Datum and Geodetic Control Networks	71
3.1	The Horizontal Datum and Horizontal Control Networks	72
3.1.1	Geodetic Origin and the Horizontal Datum	72
3.1.2	Methods of Establishing a Horizontal Control Network	74
3.1.3	Principles of Establishing a National Horizontal Control Network	76
3.1.4	Plans for Establishing a National Control Network	78
3.1.5	Establishment of a Horizontal Control Network	83
3.2	The Vertical Datum and Vertical Control Networks	87
3.2.1	The Vertical Datum and Leveling Origin	87
3.2.2	The Sounding Datum	90
3.2.3	Plans for Establishing China's National Vertical Control Network and Its Precision	91
3.2.4	Leveling Route Design, Benchmark Site Selection, and Monumentation	93
3.3	The Three-Dimensional Coordinate Datum and Satellite Geodetic Control Networks	95
3.3.1	The Three-Dimensional Coordinate Datum	96
3.3.2	Establishment of Satellite Geodetic Control Networks . . .	115
3.4	The Gravity Datum and Gravity Control Networks	120
3.4.1	The Gravity Datum	121
3.4.2	Basic Gravimetric Networks in China	123
3.4.3	Establishment of China's National Gravity Networks . . .	127
	Review and Study Questions	130
4	The Geoid and Different Height Systems	131
4.1	Gravity Potential of the Earth and Geoid	132
4.1.1	Gravity and Gravity Potential	132
4.1.2	Earth Gravity Field Model	137
4.1.3	Level Surface and the Geoid	142
4.2	Earth Ellipsoid and Normal Ellipsoid	145
4.2.1	Earth Ellipsoid	145
4.2.2	Normal Ellipsoid and Normal Gravity	147
4.2.3	Disturbing Potential	150
4.3	Height Systems	151
4.3.1	Requirements for Selecting Height Systems	151
4.3.2	Non-uniqueness of Leveled Height	152

4.3.3	Orthometric Height	153
4.3.4	Normal Height	154
4.3.5	Dynamic Height	155
4.3.6	Geopotential Number	157
4.3.7	Geodetic Height	157
4.4	Relationship and Transformation Between Different Height Systems	158
4.4.1	Relationship Between Orthometric Height, Normal Height, and Geodetic Height	158
4.4.2	Determination of Height Anomaly or Geoid Height	160
4.4.3	Grid Models of Height Anomaly or Geoid Height	162
	Review and Study Questions	163
5	Reference Ellipsoid and the Geodetic Coordinate System	165
5.1	Fundamentals of Spherical Trigonometry	165
5.1.1	Spherical Triangle	165
5.1.2	Spherical Excess	166
5.1.3	Formulae for Spherical Trigonometry	167
5.2	Reference Ellipsoid	170
5.2.1	Reference Surface for Geodetic Surveying Computations	170
5.2.2	Geometric Parameters of the Reference Ellipsoid and Their Correlations	173
5.3	Relationship Between the Geodetic Coordinate System and the Geodetic Spatial Rectangular Coordinate System	176
5.3.1	Definitions of the Geodetic Coordinate System and the Geodetic Spatial Rectangular Coordinate System	176
5.3.2	Expressions of the Ellipsoidal Normal Length	177
5.3.3	Transformation Between Geodetic and Cartesian Coordinates	179
5.4	Normal Section and Geodesic	182
5.4.1	Radius of Curvature of a Normal Section in an Arbitrary Direction	182
5.4.2	Radius of Curvature of the Meridian, Radius of Curvature in the Prime Vertical, and Mean Radius of Curvature	188
5.4.3	Length of a Meridian Arc and Length of a Parallel Arc	192
5.4.4	Reciprocal Normal Sections	200
5.4.5	The Geodesic	204
5.4.6	Solution of Ellipsoidal Triangles	211
5.5	Relationship Between Terrestrial Elements of Triangulation and the Corresponding Ellipsoidal Elements	213
5.5.1	Significance of and Requirements for Reduction of Terrestrial Triangulation Elements to the Ellipsoid	213
5.5.2	Reduction of Horizontal Directions to the Ellipsoid	215
5.5.3	Reduction of the Observed Zenith Distance	222

5.5.4	Reduction of the Observed Slope Distance to the Ellipsoid	225
5.5.5	Relationship Between Astronomical Longitude and Latitude and Geodetic Longitude and Latitude (Formula for Deflection of the Vertical)	228
5.5.6	Relationship Between Astronomical Azimuth and Geodetic Azimuth (Laplace Azimuth Formula)	231
5.6	Relationship Between the Geodetic Coordinate System and the Geodesic Polar Coordinate System	233
5.6.1	Geodesic Polar Coordinate Systems and the Solution of Geodetic Problems	233
5.6.2	Series Expansions of the Solution of the Geodetic Problem	236
5.6.3	Bessel's Formula for the Solution of the Geodetic Problem	239
5.6.4	Computations of Bessel's Direct Solution of the Geodetic Problem	249
5.6.5	Computations of Bessel's Inverse Solution of the Geodetic Problem	255
	Review and Study Questions	261
6	Gauss and UTM Conformal Projections and the Plane Rectangular Coordinate System	265
6.1	Overview of Projection	265
6.1.1	Aims of Projection	265
6.1.2	Definition of Projection	266
6.1.3	Conformal Projection and Conformality	267
6.2	General Condition for Conformal Projection	268
6.2.1	Overview	268
6.2.2	Expression of Scale Factor	269
6.2.3	General Condition for Conformal Projection	272
6.3	Fundamentals of the Gauss Projection	274
6.3.1	History and Development of the Gauss Projection	274
6.3.2	Conditions for Gauss Projection	275
6.3.3	Zone-Dividing of the Gauss Projection	276
6.3.4	Natural Coordinates and False (Biased) Coordinates	278
6.4	Direct and Inverse Solutions of the Gauss Projection and Transformation Between Adjacent Zones	279
6.4.1	Formula for Direct Solution of the Gauss Projection	279
6.4.2	Formula for Inverse Solution of the Gauss Projection	288
6.4.3	Transformation of Gauss Plane Coordinates Between Adjacent Zones	295

6.5	Elements of the Geodetic Control Network Reduced to the Gauss Plane	299
6.5.1	Reduction of the Geodetic Control Network on the Ellipsoid to the Gauss Plane	299
6.5.2	Arc-to-Chord Correction	302
6.5.3	Correction of Distance	308
6.5.4	Grid Convergence	318
6.5.5	Computation of Grid Bearing	322
6.6	Universal Transverse Mercator Projection	323
6.6.1	Definition of UTM Projection	323
6.6.2	Computational Formula for UTM Projection	324
	Review and Study Questions	326
7	Establishment of Geodetic Coordinate Systems	327
7.1	Euler Angles in Geodetic Coordinate Systems	327
7.1.1	Vector Analysis in Coordinate Transformations	327
7.1.2	Coordinate Transformations in Terms of Euler Angles as Rotation Parameters	329
7.1.3	Generalized Formulae for Deflection of the Vertical and Laplace Azimuth	332
7.2	Transformation Between Different Geodetic Coordinate Systems	332
7.2.1	Transformation Between Different Geodetic Cartesian Coordinate Systems	332
7.2.2	Transformation Between Different Geodetic Coordinate Systems	335
7.2.3	Grid Model of Coordinate Transformation	339
7.3	Classical Methods for Ellipsoid Orientation	340
7.3.1	Geodetic Origin Data and Ellipsoid Orientation	340
7.3.2	Arc Measurement Equation	343
7.3.3	Significance of the Classical Method of Ellipsoid Orientation in Understanding the Principle of Establishing a Modern Geodetic Coordinate System	348
7.4	Conventional Terrestrial Reference System	348
7.4.1	The Geocentric Coordinate System and Its Application	348
7.4.2	Definitions of the CTRS and the Conventional Terrestrial Reference Frame	352
7.4.3	Establishment and Maintenance of the CTRF	357
7.4.4	International Terrestrial Reference Frame and The World Geodetic System 1984	361
7.5	Geodetic Coordinate Systems in China	364
7.5.1	Beijing Coordinate System 1954	364
7.5.2	China's National Geodetic Coordinate System 1980 (Xi'an Coordinate System 1980)	366
7.5.3	Beijing Coordinate System 1954 (New)	371

7.5.4 Geocentric Coordinate System 1978	375
7.5.5 Geocentric Coordinate System 1988	376
7.5.6 China Geodetic Coordinate System 2000	377
Review and Study Questions	382
Bibliography	385
Index	397

Geodesy

Introduction to Geodetic Datum and Geodetic Systems

Lu, Z.; Qu, Y.; Qiao, S.

2014, XXI, 401 p. 147 illus., 15 illus. in color., Hardcover

ISBN: 978-3-642-41244-8