

Contents

1	Introduction	1
1.1	Some Examples	1
1.2	Astronomy and Computing	2
1.3	Programming Languages and Techniques	4
2	Coordinate Systems	7
2.1	Making a Start	7
2.2	Calendar and Julian Dates	14
2.3	Ecliptic and Equatorial Coordinates	17
2.4	Precession	20
2.5	Geocentric Coordinates and the Orbit of the Sun	25
2.6	The COCO Program	28
3	Calculation of Rising and Setting Times	35
3.1	The Observer's Horizon System	35
3.2	Sun and Moon	38
3.3	Sidereal Time and Hour Angle	39
3.4	Universal Time and Ephemeris Time	41
3.5	Parallax and Refraction	44
3.6	Rising and Setting Times	47
3.7	Quadratic Interpolation	48
3.8	The SUNSET Program	50
3.9	The PLANRISE Program	57
4	Cometary Orbits	59
4.1	Form and Orientation of the Orbit	59
4.2	Position in the Orbit	61
4.3	Mathematical Treatment of Kepler's Equation	65
4.4	Near-Parabolic Orbits	68
4.5	Gaussian Vectors	72
4.6	Light-Time	76
4.7	The COMET Program	77
5	Special Perturbations	85
5.1	Equation of Motion	86
5.2	Planetary Coordinates	89

5.3	Numerical Integration	91
5.4	Osculating Elements	97
5.5	The NUMINT Program	100
5.6	The Asteroid Orbital Elements Database	108
6	Planetary Orbits	111
6.1	Series Expansion of the Kepler Problem	112
6.2	Perturbation Terms	115
6.3	Numerical Treatment of the Series Expansions	118
6.4	Apparent and Astrometric Coordinates	124
6.4.1	Aberration and Light-Time	125
6.4.2	Nutation	127
6.5	The PLANPOS Program	129
7	Physical Ephemerides of the Planets	135
7.1	Rotation	135
7.1.1	The Position Angle of the Axis	136
7.1.2	Planetographic Coordinates	138
7.2	Illumination Conditions	145
7.2.1	Phase and Elongation	145
7.2.2	The Position Angle of the Sun	147
7.2.3	Apparent Magnitude	148
7.2.4	Apparent Diameter	150
7.3	The PHYS Program	150
8	The Orbit of the Moon	155
8.1	General Description of the Lunar Orbit	155
8.2	Brown's Lunar Theory	159
8.3	The Chebyshev Approximation	169
8.4	The LUNA Program	174
9	Solar Eclipses	179
9.1	Phases of the Moon and Eclipses	179
9.2	Geometry of an Eclipse	181
9.3	Geographic Coordinates and the Flattening of the Earth	186
9.4	Duration of an Eclipse	189
9.5	Solar and Lunar Coordinates	190
9.6	The ECLIPSE Program	192
9.7	Local Circumstances	200
9.8	The ECLTIMER Program	203
10	Stellar Occultations	205
10.1	Apparent Positions	206
10.2	Geocentric Conjunction	210
10.3	The Fundamental Plane	214

10.4 Disappearance and Reappearance	216
10.5 The OCCULT Program	219
10.6 Estimation of $\Delta T=ET-UT$ from Observations	229
11 Orbit Determination	231
11.1 Determining an Orbit from Two Position Vectors	231
11.1.1 The Sector-Triangle Ratio	232
11.1.2 Orbital Elements	235
11.2 The Shortened Gauss Method	239
11.2.1 The Geometry of Geocentric Observations	239
11.2.2 Successive Improvement of the Sector-Triangle Ratios	242
11.2.3 Multiple Solutions	243
11.3 The Comprehensive Gaussian Method	244
11.3.1 The Gauss-Lagrangian Equation	244
11.3.2 Improved Iteration of the Triangle-Area Ratios	247
11.3.3 Light-Time	248
11.4 The GAUSS Program	249
12 Astrometry	259
12.1 Photographic Imaging	259
12.2 Plate Constants	262
12.3 Least Squares Adjustment	264
12.4 The FOTO Program	267
12.5 The Position and Proper Motion Catalogue	272
Appendix	275
A.1 The Accompanying CD-ROM	275
A.1.1 Contents	275
A.1.2 System Requirements	277
A.1.3 Executing the Programs	277
A.2 Compiling and Linking the Programs	279
A.2.1 General Advice on Computer-Specific Modifications	279
A.2.2 Microsoft Visual C++ for Windows 95/98/NT	280
A.2.3 GNU C++ for Linux	281
A.3 List of the Library Functions	283
Symbols	289
Glossary	293
Bibliography	297
Subject Index	305