Contents

Preface to the 4th Edition **xvii**

Preface to the 3rd Edition **xxi**

Wndsn Quadrant Telemeters 3

Overview **3**
What is a Telemeter? 3
Why Low Tech? 4
Applications 5

Historical Background **13**
Background 13
1. Kamal 13
2. Nomography 17
3. Slide Rules 19

The Telemeter 25

Introduction **25**

Preparation **29**
Initial String Setup 29
Positioning the Knots 30

Tools **33**
Device Overview: Telemeter 33
Telemeter Sighting 35

Principles **37**
The Telemeter Triangle 37
Angular Size 38
Unitlessness 40
Extending the Scales 40
Powers of 10 and Scale Jumps 43
Wndsn String Theory 47
Measurement Accuracy 48

Functions **53**
Measuring Distance 53
Determining Object Sizes 57
Measuring Height 57
Measuring in the Dark 61
Thumb as Caliper 62
Small-Angle Calculations 63

Methods **73**
Height of Train vs. Length 73
Distance of Cylindrical Objects 74
Measuring the Distance to the Moon 76
Measuring Time Against the Stars 78
The Telemeter as Coordinate Scale 80
Resection 84
Triangulation 85
Trilateration 88
Triangulateration 92
Resection Error Margins 93

The Quadrant 99

Introduction **99**
What is a Quadrant? 99
What is an Inclinometer? 104

Initial Quadrant Setup **107**
Preparing the Plumb Line 107

Tools **109**
Device Overview: Quadrant 109
Transversal Scale 113
Quadrant Sighting 115
Sexagesimal System 116

Principles **123**
Parallel Translation 123
Projection via Gravity 123

Functions **125**
Quadrant and Inclinometer Operation 125
Finding Sine and Cosine 128
Using the Shadow Square 130
Finding Tangent 141
Calculating Slope 144

Methods **151**
Measuring the Depth of a Well 151
Measuring from an Elevation 153
Measuring an Elevated Object 155

Mastery of Time and Space 161

Introduction **161**

Astronomy **163**
Foundations 163
Astronomical Coordinate Systems 165
The Navigational Triangle 173
Converting between Systems 177
The Ecliptic 178
The Declination of the Sun 184

The Horary Quadrant 191

Introduction 191

Tools 193
Device Overview: Quadrant 193

Principles 197
Calculating Time 197
Seasonal ("Unequal") Hours 199
Equinoctial ("Equal") Hours 200

Functions 201
Using the Calendar 201
Using the Obliquity Arc 203
Traversing the Quadrant 203

Methods 209
Sun Calculations 209
Measuring Local Latitude 211
Measuring Sun Altitude 213
Calculating Sun Altitude 216
Calculating Sun Declination 221
Solar Time 221
Determining Time 225
Sun Compass 228
Equatorial Sundial 230
Determining Sunlight Hours 236

The Sine Quadrant 243

Introduction 243

Tools 247
Device Overview: Sine Quadrant 247
The Main Scales 248

Principles 253
Cases of Cursor Readings 253

Functions **255**
Moving the String 255
Basic Equations 256

Methods **263**
Finding Sine and Cosine 263
Great Circle Calculations 264
Determining Sunrise Bearing 268
The Hour Angle 270
Sun Azimuth from Hour Angle 274
Sun Azimuth from Sun Altitude 275
Latitude from Sun Altitude 279

Appendix 283

Metrology **283**
Uncertainty 283
Accuracy vs. Precision 284
False Precision 287
Accuracy Determinations 288
Precision of the Quadrant Telemeter 289
Calculating Scale Accuracy 289
Calibration 292

Making Of **295**
Toolmaking 295
Engravings 295
Materials 299
Brass Instrument Care 304

Reference **307**
Trigonometry 307
Spherical Trigonometry 310
Museum/Archival Description 314
Moon Heuristics 317
High Precision Calculators 319

Useful Tables **323**
Multipliers for a Given Angle 323
Radian in Degrees in MIL in MOA 328
Slope in Degrees 330
Slope in Percent 332
Calculations for 24 × 24 Shadow Square . . . 334
Calculations for 20 × 20 Shadow Square . . . 336
Sun Declination by Day 337
Length Measurement Conversions 340

Indexed Glossary **343**

Symbols **361**

Bibliography **363**

About Wndsn **371**
Contact 372

List of Figures

1 Telemeter in action. 14
2 Telemeter setup. 15
3 Example: Kamal reconstruction. 16
4 Principle of Kamal graduation. 17
5 Example nomogram: Smith chart. 19
6 Slide rule: Pickett N600-ES. 20
7 Slide rule: Faber Castell 62/83N. 21
8 Brass Telemeter. 22
9 Calculating with the nomograph scales. 26
10 Where to knot the string. 29
11 Positioning the knots. 31
12 Device overview: Telemeter. 33
13 Telemeter sighting. 35
14 The Telemeter triangle. 39
15 Using arbitrary units. 41
16 Extending the scales. 42
17 Halving the distance. 43
18 The Chinese Abacus. 45
19 Wndsn string theory. 47
20 Measuring from eye level. 48
21 Bracketing a measurement. 49
22 Operation. 54
23 Simple distance measuring. 55
24 Long distance measurement target. . . . 55
25 Cross-check on Google Maps. 56
26 Known dimension of a structure. 58
27 Measuring a parallel structure. 59

28 Google Maps. 60
29 45°. 61
30 Laser-engraved acrylic. 61
31 Thumb as caliper. 63
32 Using MIL or MOA for small angles. . . 64
33 MKS-formula. 66
34 Measuring the height of a train. 74
35 Distance of cylindrical objects. 75
36 Checking the distance with Google Maps. 76
37 Lunar eclipse on July 27 2018. 77
38 Measuring time against the stars. 78
39 Easting via Telemeter. 82
40 Northing via Telemeter. 83
41 Magnetic compass triangulation. 85
42 Gemma Frisius' triangulation. 87
43 Telemeter trilateration. 88
44 Two position fixes on a circle. 89
45 Trilateration targets. 90
46 Trilateration result. 91
47 Triangulateration. 92
48 Resection error margins. 93
49 Telemeter vs. Quadrant scale. 101
50 Universal Horary Quadrant. 102
51 Threading the string through the slot. . 107
52 Device overview: Unequal Hour Quadrant. 109
53 Highlighting the various scales. 111
54 Transversal graduations. 114
55 Quadrant sighting. 115
56 Projection via gravity. 124
57 Quadrant and inclinometer operation. . 126
58 Slope, Quadrant, and inclinometer scales. 127
59 Finding sine. 129
60 Relationships on the Shadow Square. . . 133
61 Sun altitude via LEGO brick. 135
62 Cheops pyramid height. 138
63 How to use the Shadow Square. 139
64 Sighting with the Shadow Square. 140
65 Finding tangent. 142
66 Tangent on the slope scale. 144

67 Elements in slope calculation. 145
68 Slope in degrees. 146
69 Slope in percent. 147
70 Depth of a well via Quadrant. 152
71 Depth of a well via Telemeter. 153
72 Measuring from an elevation. 154
73 Measuring an elevated object. 157
74 The celestial sphere. 164
75 Zenith and azimuth. 168
76 Right ascension. 169
77 The hour angle. 170
78 Navigational triangle. 174
79 Celestial sphere with the nav. triangle. . 175
80 Navigational triangle with formulas. . . 176
81 The ecliptic. 178
82 Solstices and equinoxes. 181
83 Axial tilt. 183
84 Sun declination by day. 184
85 Device overview: Equal Hour Quadrant. 193
86 Horary and calendar settings. 202
87 Construction of the obliquity arc. 204
88 Finding local latitude. 212
89 Polaris and Southern Cross. 212
90 Sun altitude via plumb line. 214
91 Sun altitude via gnomon. 215
92 Using the obliquity arc. 218
93 Equation of time. 226
94 Reading the unequal hours. 227
95 Reading the equal hours. 229
96 The Quadrant as a Sun compass. 230
97 AM and PM setup. 232
98 Sundial afternoon setup. 233
99 Using the sundial. 235
100 Gnomon setup. 236
101 Determining sunlight hours. 237
102 Calculating sunlight through the year. . 239
103 Paper Sine Quadrant 243
104 Device overview: Sine Quadrant. 247
105 Unit circle definitions on the Quadrant. 248

106 Reading degrees from the cursor. 254
107 Basic Sine Quadrant equations 1. 257
108 Basic Sine Quadrant equations 2. 259
109 Finding sine with the Sine Quadrant. . . 264
110 Great circle calculation. 267
111 Stages of twilight. 269
112 Determine sunrise bearing. 270
113 Hour angle and half-arc of daylight. . . 274
114 Sun azimuth from Sun altitude. 277
115 North and south from Sun azimuth. . . 278
116 The Indian Circle. 278
117 Local latitude from Sun altitude. 280
118 Accuracy: trueness and precision. 286
119 Sample measurement uncertainty. 292
120 Calibrating device resolution. 293
121 Wndsn fecit. 296
122 Wndsn single-line fonts. 296
123 Voyager 'Golden Record'. 297
124 Engraved instructions. 298
125 The "greedy" algorithm. 299
126 Brass patina. 305
127 Unit circle. 309
128 Spherical triangle. 311
129 Moon clock. 318

List of Tables

1 Scale configuration. 35
2 Unitless example. 40
3 Max. angular subtension. 44
4 Sexagesimal fractions. 119
5 Comparison of coordinate systems. . . . 166
6 Sun declination via longitude. 185
7 Sun declination by month. 206
8 Equation of time 226
9 Precision of the scales. 290
10 Sample device uncertainty margins. . . . 290
11 Sample measurement uncertainty. 291
12 Sample device resolution. 294
13 Moon heuristics. 320
14 Multipliers for a given angle. 323
15 Radians in degrees in MIL in MOA. . . 328
16 Slope in percent, degrees, and fractions. 330
17 Slope in degrees and percent. 332
18 Calculations for 24 × 24 Shadow Square. 334
19 Calculations for 20 × 20 Shadow Square. 336
20 Sun declination by day (JAN-JUN) . . . 337
21 Sun declination by day (JUL-DEC) . . . 339
22 Length measurement conversions. 341

List of Equations

1 Distance from angular size 37
2 MKS-formula 66
3 Distance from Umbra Recta 132
4 Height from Umbra Versa 132
5 Shadow length from Sun altitude 134
6 Sun altitude from shadow length 134
7 Hour angle via Sun azimuth 177
8 Declination via Sun azimuth 177
9 Sun azimuth via hour angle 177
10 Sun altitude via hour angle 177
11 Obliquity of the ecliptic 184
12 Sun declination via longitude 185
13 Time from Sun altitude 198
14 Sun altitude at noon 216
15 Solar zenith angle 217
16 Sun declination from Sun altitude 221
17 Equation of Time 225
18 Great circle bearing 266
19 Bearing (or amplitude) of rising Sun . . 268
20 Azimuth of rising Sun 268
21 Hour angle of sunrise from latitude . . . 272
22 Hour angle via Sun altitude 272
23 Hour angle via Sun azimuth 272
24 Sun altitude from hour angle 272
25 Sun azimuth for a given hour 274
26 Sun azimuth from hour angle 275
27 Sun azimuth from altitude 276

28 Latitude from Sun altitude 279
29 Uncertainty 283
30 Device accuracy 288
31 Unit circle definitions 307
32 Trigonometric identities 308
33 Law of sines 309
34 Spherical right-angled triangle identities 312
35 Spherical law of sines 313
36 Spherical cosines law for sides 313
37 Spherical cosines law for angles 313
38 Spherical sine-cosine law 314
39 Slope in degrees 330
40 Slope in percent 332