

Contents

Preface — V

Abbreviations — XXI

1 Introduction to your book — 1

- 1.1 Chapter learning outcomes — 1
- 1.2 Why take a naked-eye astronomy class? — 1
- 1.3 Naked-eye astronomy in days gone by — 2
- 1.4 Astronomy *versus* astrology — 4
 - 1.4.1 What is the difference between astronomy & astrology? — 4
 - 1.4.2 Value of theories — 4
 - 1.4.3 Astrological theories fail the test — 5
- 1.5 Architecture records naked-eye astronomy before writing — 5
 - 1.5.1 Orientations & alignments — 6
 - 1.5.2 Example: Illinois, United States — 8
 - 1.5.3 Archeoastronomy in practice — 8
- 1.6 The typical versus the atypical — 10
- 1.7 Commonality of your sky — 10
- 1.8 Chapter summary — 11
- 1.9 Chapter review — 11

2 Your eyes — 12

- 2.1 Chapter learning outcomes — 12
- 2.2 Your field of view — 12
- 2.3 Bright or dim? — 12
 - 2.3.1 Dark adaptation — 13
 - 2.3.2 Impediments to dark adaptation — 14
 - 2.3.3 A trick to improve your sensitivity to light — 15
 - 2.3.4 Limiting magnitude — 15
- 2.4 Special precautions for observing the Sun — 16
- 2.5 Warning — 18
- 2.6 Angular resolution — 18
- 2.7 Color — 20
 - 2.7.1 Your visible spectrum — 20
 - 2.7.2 Not all color vision is alike — 21
- 2.8 You can see a lot – but not everything — 21
- 2.9 Time to get started! — 22
- 2.10 Chapter summary — 23
- 2.11 Chapter review — 23

3 The atmosphere — 24

- 3.1 Chapter learning outcomes — 24
- 3.2 Air mass — 24
- 3.3 Preferential transmission of light — 25
- 3.4 The quality of the sky for viewing varies — 29
 - 3.4.1 Transparency — 29
 - 3.4.2 Seeing — 30
- 3.5 Twilight — 31
 - 3.5.1 Civil twilight — 32
 - 3.5.2 Nautical twilight — 32
 - 3.5.3 Astronomical twilight — 32
 - 3.5.4 The “Belt of Venus” (a misnomer) — 33
- 3.6 Light pollution — 35
 - 3.6.1 Wasted light — 35
 - 3.6.2 What can you do about light pollution? — 37
- 3.7 Chapter summary — 38
- 3.8 Chapter review — 39

4 The dome of your sky — 40

- 4.1 Chapter learning outcomes — 40
- 4.2 Significance of and direction in your sky dome — 40
- 4.3 “Distance” & “Place” — 41
- 4.4 Altitude — 41
- 4.5 Azimuth — 42
- 4.6 Measuring angles in your sky — 43
- 4.7 Cardinality — 45
 - 4.7.1 The compass — 47
 - 4.7.2 Alternatives to cardinality — 47
- 4.8 The “Heavenly Firmament” — 48
- 4.9 Horizon events — 49
 - 4.9.1 Heliacal rising & setting — 49
 - 4.9.2 Example: Wyoming, United States — 51
 - 4.9.3 Acronical rising & setting — 52
- 4.10 Chapter summary — 53
- 4.11 Chapter review — 53

5 Stars — 55

- 5.1 Chapter learning outcomes — 55
- 5.2 Backdrop of your sky — 55
 - 5.2.1 Constellations — 55
 - 5.2.2 Constellations made official — 57
 - 5.2.3 Asterisms — 59

5.3	Star names — 64
5.4	Stellar brightness — 65
5.4.1	Can stellar size be seen? — 65
5.4.2	Brightness <i>versus</i> luminosity — 66
5.4.3	Stellar record holders — 67
5.4.4	Stellar magnitudes — 67
5.5	Stellar color — 68
5.6	Unresolvable groups of stars — 69
5.6.1	The Milky Way — 69
5.6.2	Example: Australia — 71
5.7	Chapter summary — 72
5.8	Chapter review — 72

6 Navigating your sky — 73

6.1	Chapter learning outcomes — 73
6.2	Rotation of the Earth — 73
6.2.1	What is moving? — 73
6.2.2	Our language & relative motion — 74
6.3	Rising & setting — 75
6.4	One night — 76
6.5	Your horizon & zenith — 77
6.6	Your celestial meridian — 79
6.7	Example: Egypt — 80
6.7.1	The Great Pyramid of Khufu — 80
6.7.2	Egyptian connection with the sky — 81
6.7.3	A solution to the “Mystery” of Khufu — 83
6.8	Circumpolar stars — 83
6.9	Example: Egypt (Continued) — 86
6.10	Chapter summary — 87
6.11	Chapter review — 87

7 The celestial sphere — 89

7.1	Chapter learning outcomes — 89
7.2	Two ways to describe things celestial — 89
7.2.1	Your personal reference system — 89
7.2.2	A universal reference system — 90
7.3	Celestial equator — 92
7.4	Celestial poles — 93
7.5	Where you live affects your sky — 93
7.5.1	North celestial hemisphere & south celestial hemisphere — 94
7.5.2	Rising & setting azimuth — 95
7.6	Tour of skies at different latitudes — 95

7.6.1	Traveling northward —	95
7.6.2	Traveling southward —	97
7.7	Terrestrial/nautical navigation —	97
7.7.1	Finding your latitude —	98
7.7.2	Finding your longitude —	99
7.8	Revolution of the Earth —	99
7.9	Combined effect of the Earth's rotation & revolution —	101
7.10	Night skies of spring, summer, autumn, & winter —	101
7.11	Example: Mexico Valley —	104
7.12	Chapter summary —	106
7.13	Chapter review —	106

8 Celestial coordinates and the precession of the Equinoxes — 107

8.1	Chapter learning outcomes —	107
8.2	Proper motion —	107
8.3	Coordinate system on the Celestial Sphere —	108
8.3.1	Declination —	109
8.3.2	Right ascension —	109
8.4	Wobble of the Earth's axis —	111
8.4.1	Precession —	112
8.4.2	The Great Year —	113
8.5	Different pole stars —	114
8.6	No pole star at all —	116
8.6.1	Finding the South Celestial Pole —	117
8.6.2	Example: Brazil —	117
8.7	Precession & chronology —	117
8.7.1	An age when the North Star was not Polaris —	117
8.7.2	Precession affects rising and setting dates —	118
8.7.3	First point of Aries —	118
8.8	Adding up what affects the appearance of your sky —	120
8.9	Chapter summary —	120
8.10	Chapter review —	121

9 The Sun — 122

9.1	Chapter learning outcomes —	122
9.2	Morning, noon & night —	122
9.2.1	How we set our clocks —	123
9.2.2	Hours —	126
9.2.3	Time zones —	127
9.3	The ecliptic —	129
9.3.1	The zodiac —	129
9.3.2	(Mis)use of the zodiac in astrology —	130

9.3.3	Ecliptical coordinates —	131
9.4	Why do we have seasons? —	131
9.4.1	Angular momentum —	131
9.4.2	Obliquity —	133
9.4.3	The changing altitudes of the sun throughout the year —	134
9.5	Chapter summary —	137
9.6	Chapter review —	138
10	Your year through the seasons —	139
10.1	Chapter learning outcomes —	139
10.2	A celestial map —	139
10.2.1	Adding the Sun to your map —	141
10.2.2	Implications of your map-as-calendar —	142
10.3	Solstices —	142
10.3.1	Keeping track of the Solstices —	143
10.3.2	Example: Ireland —	143
10.3.3	Azimuth of the Sun during different seasons —	145
10.3.4	Twilight during different seasons —	146
10.4	Equinoxes —	147
10.4.1	Limb & vertex —	148
10.4.2	Sunrise, sunset, & atmospheric refraction —	149
10.5	Divisions on your celestial map —	149
10.6	Cross-quarter days —	151
10.6.1	Names of cross-quarter days —	152
10.6.2	Contemporary cross-quarter days —	153
10.7	Seasons are not of equal length —	154
10.8	Not all seasons are based upon astronomy —	155
10.9	Chapter summary —	156
10.10	Chapter review —	156
11	Seasonal insolation and daytime/nighttime —	158
11.1	Chapter learning outcomes —	158
11.2	Insolation —	158
11.2.1	Efficiency of heating by the Sun —	158
11.2.2	Example: Chaco Canyon, Colorado Plateau, North America —	160
11.2.3	Thermal lag of the Earth —	161
11.3	Winter versus summer daytime & nighttime —	161
11.3.1	From terminator to terminator in summer —	162
11.3.2	From terminator to terminator in winter —	164
11.4	Seasons at different latitudes —	165
11.4.1	The Arctic & Antarctic circles —	165
11.4.2	The Tropics of Cancer & Capricorn —	168

11.4.3	Erathosthenes —	172
11.4.4	Duration of twilight —	173
11.5	Chapter summary —	174
11.6	Chapter review —	174
12	The Moon —	176
12.1	Chapter learning outcomes —	176
12.2	Differences between the two luminaries —	176
12.3	Does the Moon affect the Earth? —	177
12.4	Tides —	177
12.5	Albedo —	181
12.5.1	Lunar features —	182
12.5.2	What do <i>you</i> see on the Moon? —	186
12.5.3	Moon as mirror —	186
12.5.4	Color of the Moon? —	188
12.6	How much of the Moon's sphere you can see? —	188
12.6.1	Geometric (optical) librations —	189
12.6.2	Physical libration —	190
12.7	Observed change on the Moon? —	191
12.8	Representation of the naked-eye Moon —	192
12.9	Chapter summary —	194
12.10	Chapter review —	194
13	From New Moon to Full Moon —	195
13.1	Chapter learning outcomes —	195
13.2	Two kinds of month —	195
13.2.1	Sidereal month —	196
13.2.2	Synodic month —	198
13.3	What causes the phases of the Moon? —	199
13.3.1	You see the part of the Moon's illuminated hemisphere that is facing you —	199
13.3.2	Phases of your own —	201
13.4	New Moon —	201
13.5	Crescent Moon —	202
13.5.1	Sighting the Crescent Moon —	203
13.5.2	The Moon grows "older" —	203
13.6	First Quarter Moon —	205
13.6.1	Why the phrase "Half Moon" is incorrect —	206
13.6.2	Aristarchus's attempt to measure the lunar distance —	206
13.7	Gibbous Moon —	207
13.8	Full Moon —	209
13.8.1	You are most likely to see a Full Moon —	210

- 13.8.2 How full is full? — **211**
- 13.9 Moon Illusion — **211**
- 13.9.1 Distance from the Moon anywhere on the Earth does not affect lunar apparent size — **212**
- 13.9.2 Potential causes of the Moon Illusion — **213**
- 13.10 Chapter summary — **214**
- 13.11 Chapter review — **215**

14 Full Moon to New Moon — 216

- 14.1 Chapter learning outcomes — **216**
- 14.2 Only Full Moons each have their own names — **216**
- 14.3 Angle of illumination — **217**
- 14.4 What is a Blue Moon? — **218**
- 14.5 Second Gibbous Moon of the month — **220**
- 14.6 Third Quarter Moon — **222**
- 14.7 Second Crescent Moon of the month — **223**
- 14.7.1 Cusps of the Moon — **225**
- 14.7.2 (Lunar) Terminator illusion — **226**
- 14.8 Earthshine — **228**
- 14.8.1 What causes earthshine? — **228**
- 14.8.2 How & when to see earthshine — **229**
- 14.9 Return of the New Moon — **230**
- 14.9.1 Waxing & waning — **231**
- 14.9.2 Practice! — **231**
- 14.10 Fixing the calendar — **232**
- 14.10.1 The luni-solar calendar — **233**
- 14.10.2 The Julian calendar — **234**
- 14.10.3 The Gregorian calendar — **235**
- 14.10.4 Other calendars of Interest — **236**
- 14.11 Chapter summary — **236**
- 14.12 Chapter review — **237**

15 Further lunar cycles — 239

- 15.1 Chapter learning outcomes — **239**
- 15.2 Lunar retardation — **239**
- 15.3 Lunar altitude — **239**
- 15.3.1 Moonrise/moonset — **240**
- 15.3.2 Lunar culmination — **241**
- 15.4 Lunar azimuth — **243**
- 15.4.1 Standstills — **243**
- 15.4.2 Maximum & minimum lunar standstill — **244**
- 15.4.3 Special latitudes defined by the Moon — **246**

- 15.5 Who pays attention to the changing path of the Moon? — **246**
- 15.5.1 Difficulties encountered while attempting to observe lunar alignments — **246**
- 15.5.2 Example: Colorado, United States — **247**
- 15.6 Changing brightness of the Full Moon — **249**
- 15.7 *Abandon* the calendar? — **250**
- 15.8 Chapter summary — **251**
- 15.9 Chapter review — **251**

16 Eclipses — 252

- 16.1 Chapter learning outcomes — **252**
- 16.2 A total eclipse of the Sun begins — **252**
- 16.3 Totality — **254**
- 16.4 A total eclipse of the Sun ends — **258**
- 16.5 What causes an eclipse of the Sun? — **259**
- 16.5.1 Cosmic coincidence — **260**
- 16.5.2 Lunar nodes — **263**
- 16.5.3 Solar eclipse timing — **265**
- 16.5.4 Solar eclipse centerline — **267**
- 16.6 Annular eclipses — **268**
- 16.7 Eclipse magnitude — **271**
- 16.8 Solar eclipse eye safety — **272**
- 16.9 Eclipses of the Moon — **273**
- 16.9.1 What causes a lunar eclipse? — **274**
- 16.9.2 Penumbral eclipses — **275**
- 16.10 Chapter summary — **277**
- 16.11 Chapter review — **278**

17 Predicting eclipses — 279

- 17.1 Chapter learning outcomes — **279**
- 17.2 Factors involved in eclipse prediction — **279**
- 17.2.1 Nodical month — **279**
- 17.2.2 Anomalistic month — **280**
- 17.2.3 Eclipse seasons — **281**
- 17.3 Attempts at prediction — **283**
- 17.3.1 The saros — **283**
- 17.3.2 Success! — **285**
- 17.3.3 Example: Norway — **286**
- 17.4 Eclipse duration — **287**
- 17.5 Eclipse paths — **289**
- 17.6 Scale — **291**
- 17.7 Your chance of seeing an eclipse — **291**

- 17.8 Chapter summary — **293**
- 17.9 Chapter review — **294**

18 Planets — 295

- 18.1 Chapter learning outcomes — **295**
- 18.2 How to tell a planet from a star — **295**
- 18.3 Motion of planets in your sky — **296**
- 18.3.1 Sidereal & synodic periods of the planets — **297**
- 18.3.2 Prograde motion — **298**
- 18.4 Inferior planets — **299**
- 18.4.1 Planetary elongation — **299**
- 18.4.2 Retrograde motion — **301**
- 18.4.3 Inferior & superior conjunction — **301**
- 18.4.4 Venus — **302**
- 18.4.5 More on planetary brightness — **303**
- 18.4.6 Mercury — **305**
- 18.5 Superior planets — **305**
- 18.5.1 Conjunction & opposition — **305**
- 18.5.2 Retrograde loop — **307**
- 18.5.3 Other differences between inferior & superior planets — **308**
- 18.5.4 Mars — **309**
- 18.5.5 Jupiter — **310**
- 18.5.6 Saturn — **311**
- 18.5.7 Uranus? — **312**
- 18.6 Keeping track of the planets — **313**
- 18.6.1 Example: Mesoamerica — **313**
- 18.6.2 Importance of planets — **315**
- 18.7 Days of the week — **315**
- 18.8 Chapter summary — **317**
- 18.9 Chapter review — **318**

19 Your solar system — 319

- 19.1 Chapter learning outcomes — **319**
- 19.2 Solar disk — **319**
- 19.2.1 Limb darkening — **319**
- 19.2.2 Sunspots — **320**
- 19.2.3 Sunspot cycle — **323**
- 19.2.4 Aurorae — **325**
- 19.3 Planetary conjunctions — **326**
- 19.4 Occultations — **329**
- 19.5 Transits — **331**
- 19.6 Meteors — **332**

19.6.1	Cause of meteors —	332
19.6.2	Bolides —	334
19.6.3	Meteor showers —	335
19.7	Asteroids —	337
19.8	Interplanetary dust —	338
19.9	Comets —	339
19.9.1	Comet behavior in your sky —	341
19.9.2	Comet tails —	342
19.9.3	Long- and short-period comets —	343
19.9.4	Great comets —	345
19.10	Chapter summary —	346
19.11	Chapter review —	346
20	Your naked-eye universe —	348
20.1	Chapter learning outcomes —	348
20.2	Binary stars —	348
20.3	Variable stars —	349
20.4	Novae and supernovae —	352
20.5	Deep-sky objects —	356
20.5.1	Open star clusters and nebulae —	356
20.5.2	Globular star clusters —	357
20.5.3	Galaxies —	359
20.5.4	The scope of naked-eye astronomy is enormous —	361
20.6	The universe: is your ability to see the sky pre-ordained? —	364
20.6.1	Olbers's paradox —	364
20.6.2	Do more objects in the universe emit or absorb light? —	365
20.6.3	Olbers's paradox points toward a description of the entire universe! —	366
20.7	Chapter summary —	366
20.8	Chapter review —	367

Afterword — 369

Appendices

I	The most dependable of clocks —	373
II	Selected heliacal star sets and rises —	375
III	The constellations —	377

IV	The Greek alphabets —	379
V	Stars that rise and set at mid-northern latitudes —	381
VI	Northern circumpolar stars —	383
VII	Southern circumpolar stars —	385
VIII	Zodiac constellations used in astrology —	387
IX	Northern evening constellations by season —	389
X	Year, month, and day lengths —	391
XI	Properties of naked-eye planets, satellites, and asteroids —	393
XII	Apparent magnitudes of the planets —	395
XIII	Selected annual meteor showers —	397
XIV	Selected naked-eye optical double stars —	399
XV	Naked-eye recurring novae —	401
XVI	Selected naked-eye variable stars —	403
XVII	Selected naked-eye open clusters —	405
XVIII	Selected naked-eye globular clusters —	407
XIX	Selected naked-eye nebulae —	409
XX	Naked-eye galaxies —	411
	Further reading —	413
	Glossary —	415
	Index —	433

