

Contents

Preface	xi
1 ■ Early Astronomy	1
1.1 The Celestial Sphere	1
1.2 Coordinate Systems on a Sphere	3
1.3 Celestial Motions	9
1.4 Basic Timekeeping	16
1.5 Solar and Sidereal Time	17
1.6 Calendars	25
2 ■ Emergence of Modern Astronomy	29
2.1 Early Greek Astronomy	29
2.2 Ptolemaic Astronomy	34
2.3 Copernican Astronomy	38
2.4 Galileo: The First Modern Scientist	47
2.5 Kepler's Laws of Planetary Motion	50
2.6 Proof of the Earth's Motion	52
2.6.1 Rotation of the Earth	53
2.6.2 Revolution of the Earth	57
3 ■ Orbital Mechanics	61
3.1 Deriving Kepler's Laws	62
3.1.1 Kepler's Second Law	62
3.1.2 Kepler's First Law	66
3.1.3 Kepler's Third Law	72
3.2 Orbital Energetics	74
3.3 Orbital Speed	75
3.4 The Virial Theorem	78

4 ■ The Earth–Moon System	83
4.1 Precession	83
4.2 Tides	84
4.3 Limits on the Size of Orbits	92
4.3.1 Minimum Orbit Size: Roche Limit	93
4.3.2 Maximum Orbit Size: Hill Radius	95
4.4 Phases of the Moon	97
4.5 Rotation of the Moon	99
4.6 Eclipses	102
5 ■ Interaction of Radiation and Matter	111
5.1 Atomic Structure	111
5.2 Atomic Processes	118
5.3 Emission and Absorption Spectra	121
5.4 The Equation of Radiative Transfer	127
5.5 The Curve of Growth	130
5.6 Local Thermodynamic Equilibrium	133
5.7 Blackbody Radiation	137
6 ■ Astronomical Detection of Light	146
6.1 The Telescope as a Camera	146
6.2 Refracting and Reflecting Telescopes	151
6.3 Quality of Images	155
6.4 Astronomical Instruments and Detectors	159
6.5 Observations and Photon Counting	161
6.6 Observations at Other Wavelengths	165
6.7 Modern Telescopes	168
7 ■ The Sun	172
7.1 Observable Layers of the Sun	172
7.2 Solar Activity	181
7.3 Angular Momentum of the Sun	189
8 ■ Overview of the Solar System	194
8.1 Two Types of Planets	194
8.2 Physical Properties of Planets	196
8.3 Formation of the Solar System	203

9 ■ Earth and Moon	209
9.1 The Earth's Interior	209
9.2 The Earth's Atmosphere	213
9.3 The Earth's Magnetosphere	220
9.4 The Moon's Interior and Surface	221
9.5 The Origin of the Moon	227
Appendix: Radioactive Dating	228
10 ■ The Planets	232
10.1 Terrestrial Planets	232
10.1.1 Mercury	232
10.1.2 Venus	235
10.1.3 Mars	239
10.2 Jovian Planets	243
10.2.1 Jupiter and Saturn	244
10.2.2 Satellites of Jupiter and Saturn	252
10.2.3 Uranus and Neptune	256
10.3 Planetary Rings	259
11 ■ Small Bodies in the Solar System	266
11.1 Asteroids	266
11.2 Trans-Neptunian Objects	271
11.3 Comets	277
11.4 Meteoroids and Dust	280
12 ■ The Solar System in Perspective	290
12.1 Comparative Planetology Within the Solar System	290
12.2 Origin of the Solar System	292
12.3 Detecting Exoplanets	294
12.4 Properties of Exoplanets	304
13 ■ Properties of Stars	307
13.1 How Far Is a Star?	307
13.2 How Bright Is a Star?	309
13.3 How Hot Is a Star?	313
13.4 How Big Is a Star?	318

13.5	How Massive Is a Star?	322	
13.5.1	Visual Binaries	322	
13.5.2	Spectroscopic Binaries	326	
13.5.3	Eclipsing Binaries	329	
13.6	How Are Mass, Radius, and Luminosity Related?	330	
	Appendix: Determination of Bolometric Corrections	332	
14	Stellar Atmospheres		336
14.1	Hydrostatic Equilibrium	336	
14.2	Spectral Classification	339	
14.3	Luminosity Classes	343	
14.4	Hertzsprung–Russell Diagrams	345	
15	Stellar Interiors		350
15.1	Equations of Stellar Structure	350	
15.1.1	Energy Transport in Stars	352	
15.1.2	Radiative Transport	353	
15.1.3	Convective Transport	356	
15.2	Energy Generation in Stars	359	
15.3	Nuclear Fusion Reactions	362	
15.4	Modeling Stellar Interiors	369	
	Appendix: Random Walk Processes	372	
16	The Interstellar Medium		376
16.1	Interstellar Dust	376	
16.1.1	Evidence for Interstellar Dust	376	
16.1.2	Observable Effects of Dust on Starlight	378	
16.2	Interstellar Gas	380	
16.3	The Physics of Non-LTE Gases	384	
16.3.1	Ionization Balance	384	
16.3.2	Thermal Balance	387	
17	Formation and Evolution of Stars		393
17.1	Star Formation	393	
17.2	Evolution of Sun-like Stars	398	
17.3	Pulsating Variable Stars	402	

18 ■ Stellar Remnants	409
18.1 White Dwarfs	410
18.1.1 Degeneracy Pressure	410
18.1.2 Mass–Radius Relationship	412
18.2 Neutron Stars and Pulsars	416
18.3 Black Holes	423
18.4 Novae and Supernovae	426
19 ■ Our Galaxy	433
19.1 Overview: Morphology of Our Galaxy	433
19.2 Overview: Kinematics and Dynamics of our Galaxy	439
19.3 Local Stellar Motions	444
19.4 The Local Standard of Rest	448
19.5 Differential Rotation of our Galaxy	451
19.6 Determining the Rotation Curve	456
19.7 The Nucleus of our Galaxy	461
20 ■ Galaxies	467
20.1 Galaxy Classification	468
20.2 Galaxy Spectra	474
20.3 Supermassive Black Holes in Galaxies	480
20.4 Distances to Galaxies	482
20.5 The Hubble Law	484
21 ■ Active Galaxies	489
21.1 Types of Active Galaxies	490
21.1.1 Seyfert Galaxies	490
21.1.2 Quasars	491
21.1.3 Radio Galaxies	495
21.2 Accretion by Supermassive Black Holes	497
21.2.1 Energetics	497
21.2.2 The Eddington Limit	497
21.2.3 Accretion Disks	499
21.3 The Structure of AGNs and Unified Models	501
21.4 Quasars over Cosmic History	503
21.5 Probing the Intergalactic Medium	505
Appendix: Superluminal Radio Sources	506

22 ■ Clusters and Superclusters	511
22.1 Clusters of Galaxies	511
22.2 When Galaxies Collide!	515
22.3 Superclusters and Voids	520
23 ■ Cosmology	526
23.1 Basic Cosmological Observations	527
23.2 Cosmology à la Newton	533
23.3 Cosmology à la Einstein	536
23.4 Metrics of Spacetime	543
23.5 The Friedmann Equation	546
24 ■ History of the Universe	551
24.1 The Consensus Model	551
24.2 The Accelerating Universe	559
24.3 The Early Universe	564
24.4 The Very Early Universe	568
A ■ Astronomical Data	575
Bibliography	583
Credits	585
Index	589