

Stellar Structure and Evolution

Marc Pinsonneault

The Ohio State University

Barbara Ryden

The Ohio State University



CAMBRIDGE
UNIVERSITY PRESS

Contents

<i>Preface</i>	<i>page xi</i>
I Properties of Stars	1
1.1 Observing the Sun	2
1.2 Observing Other Stars	8
1.3 Correlations among Properties	19
1.4 Observing Clusters of Stars	25
Exercises	28
2 Equations of Stellar Structure	30
2.1 Stars Conserve Mass	30
2.2 Stars Are in Hydrostatic Equilibrium	32
2.3 Stars Are in Thermal Equilibrium	34
2.4 Stars Transport Energy	36
Exercises	41
3 Equations of State	43
3.1 Central Pressure of Stars	44
3.2 Quantum Statistics	46
3.3 Ideal Gas Pressure	50
3.4 Degeneracy Pressure	53
3.5 Radiation Pressure	59
Exercises	62
4 Stellar Energy Transport	64
4.1 Opacity	64

4.2	Convection	75
4.3	Mixing Length Theory	82
4.4	Convective Overshoot	86
	Exercises	87
5	Stars as Fusion Reactors	89
5.1	Quantum Tunneling and Fusion	90
5.2	Energy Generation and Composition Change	95
5.3	The pp Chain	100
5.4	The CNO Bi-cycle	108
5.5	Triple Alpha and Beyond	112
	Exercises	116
6	Main Sequence Stars	117
6.1	Internal Structure	119
6.2	Polytropes	121
6.3	Homology	126
6.4	Solar Models	132
6.5	Zero Age Main Sequence Models	138
	Exercises	144
7	Star Formation: Before the Main Sequence	146
7.1	Molecular Clouds and Instability	147
7.2	Isothermal Collapse and Fragmentation	153
7.3	Protostars	156
7.4	Pre-Main Sequence Stars	158
7.5	Birthline and Deuterium Burning	164
7.6	Initial Mass Function	168
	Exercises	171
8	Evolved Stars: After the Main Sequence	173
8.1	Building a Helium Core	175
8.2	Schönberg–Chandrasekhar Limit	179
8.3	Shell Hydrogen Burning and Red Giants	184
8.4	Helium Ignition and Core Helium Burning	189
8.5	Asymptotic Giant Branch	196
8.6	Making s-Process Elements	199

8.7	Superwinds and Planetary Nebulae	203
	Exercises	206
9	Ex-Stars	209
9.1	White Dwarfs	211
9.2	Neutron Stars and Black Holes	219
9.3	Core Collapse Supernovae	223
9.4	Making r-Process Elements	228
	Exercises	230
10	Rotating Stars	231
10.1	Effects of Rotation on Structure	231
10.2	Meridional Circulation	234
10.3	Angular Momentum Transport	238
10.4	Rotation and Star Formation	243
10.5	Rotation on the Main Sequence	246
10.6	Stellar Winds and Angular Momentum	250
	Exercises	254
11	Pulsating Stars	255
11.1	Adiabatic Radial Pulsations	257
11.2	Non-adiabatic Radial Pulsations	262
11.3	Adiabatic Non-radial Pulsations	268
11.4	Observational Asteroseismology	275
	Exercises	279
12	Binary Stars	281
12.1	Observed Properties of Binaries	282
12.2	Close Binaries	287
12.3	Cataclysmic Variables	295
12.4	Banging Stars Together	300
	Exercises	304
Appendix A	Constants and Units	306
Appendix B	Properties of Example Stars	308
	<i>Further Reading, Bibliography, and Figure Credits</i>	309
	<i>Index</i>	320