

Contents

<i>Preface</i>	<i>page xi</i>
I Introduction	1
1.1 History of Interstellar Studies	7
1.2 Approaching Equilibrium	14
1.3 Heating and Cooling in the ISM	20
1.4 Stable and Unstable Equilibrium	26
Exercises	29
2 Cold Neutral Medium	31
2.1 Equation of Radiative Transfer	33
2.2 Absorbers and Emitters	36
2.3 Building Absorption Lines	43
2.4 Curve of Growth	46
Exercises	52
3 Warm Neutral Medium	54
3.1 Twenty-One Centimeter Emission and Absorption	55
3.2 Radiative Transfer of Line Emission	59
3.3 Exciting Hyperfine Energy Levels	64
Exercises	68
4 Warm Ionized Medium and Ionized Nebulae	70
4.1 Photoionization and Radiative Recombination	71
4.2 Strömgren Spheres	75

viii	Contents
4.3	Heating and Cooling in H II Regions 81
4.4	Temperature and Density Diagnostics 88
4.5	Dynamics of H II Regions 95
	Exercises 102
5	Hot Ionized Medium 106
5.1	Shocking Information 107
5.2	Supernova Remnants 113
5.3	Ionizing, Heating, and Cooling 120
5.4	Observing the Hot Ionized Medium 125
	Exercises 128
6	Interstellar Dust 130
6.1	Observed Properties of Dust 132
6.2	Optical Properties of Grains 135
6.3	Composition, Shape, and Size of Grains 140
6.4	Heating and Cooling Grains 146
6.5	Making and Breaking Grains 148
	Exercises 152
7	Molecular Clouds 154
7.1	Interstellar CO 157
7.2	From CO to H ₂ 162
7.3	Heating and Cooling Molecular Gas 168
7.4	Making and Breaking Molecules 170
	Exercises 179
8	Circumgalactic and Intracluster Gas 181
8.1	Circumgalactic Medium: Our Galaxy 182
8.2	Circumgalactic Medium: Other Galaxies 186
8.3	Intracluster Medium 189
	Exercises 196
9	Diffuse Intergalactic Medium 198
9.1	Gunn–Peterson Effect 198
9.2	Recombination 203
9.3	Reionization 205

Contents**ix**

9.4 Lyman Alpha Forest	213
Exercises	218
10 Warm-Hot Intergalactic Medium	220
10.1 Simulations	221
10.2 Observations	225
Exercises	228
<i>Bibliography, References, and Figure Credits</i>	231
<i>Constants and Units</i>	243
<i>Index</i>	245