

Contents

<i>Figures</i>	<i>xi</i>
<i>Preface</i>	<i>xiii</i>
1 Partially Ionized Plasmas Here and Everywhere	1
1.1 Plasma, a Matter of State	1
1.2 Partial Ionization in the Early Universe	1
1.3 Reionization Phase of the Universe	6
1.4 Partially Ionized Plasma on Cosmic Scales	7
1.5 Molecular Clouds	7
1.6 Accretion Disks	8
1.7 Interstellar Partially Ionized Plasma	9
1.8 Solar Atmosphere	9
1.9 Cometary Tails	14
1.10 The Ionosphere	14
1.11 Partially Ionized Plasmas in Laboratory	14
1.12 Cold Plasmas in Medicine	16
1.13 Summary	17
1.14 Problems	17
2 Multifluid Description of Partially Ionized Plasmas	18
2.1 Statistical Description	18
2.1.1 The Maxwellian velocity distribution function	19
2.2 Local Maxwell–Boltzmann Distribution Function	25
2.2.1 The Boltzmann equation	25
2.2.2 The fluid formalism	28
2.2.3 The stress tensor	33
2.2.4 Validity of the fluid picture	36
2.2.5 The Boltzmann collision integral	37
2.3 Three-fluid Description of a Partially Ionized Plasma	37
2.4 Two-fluid Description of a Partially Ionized Plasma	41
2.4.1 The MHD fluid	41
2.4.2 Restrictions on the MHD fluid	46
2.4.3 The neutral fluid	47
2.4.4 The two-fluid system	47

2.5 Single Partially Ionized Fluid—the SPIF	48	4.1.2 Polarization of TWIP waves	113
2.6 Weakly Ionized Plasma	54	4.1.3 Energy partition in TWIP waves	114
2.7 Summary	56	4.1.4 Dissipation of the TWIP waves	115
2.8 Problems	57	4.1.5 Longitudinal waves in weakly ionized plasmas—the LWIP waves	117
3 Equilibrium of Partially Ionized Plasmas	59	4.1.6 LWIP waves with $\vec{k} \perp \vec{B}_0$	118
3.1 The Equilibrium	59	4.1.7 Polarization of LWIP waves with $\vec{k} \perp \vec{B}_0$	119
3.2 The Equilibrium Velocity Distribution Function	59	4.1.8 Energy partition for LWIP waves with $\vec{k} \perp \vec{B}_0$	119
3.3 Collisional Forces	61	4.1.9 Dissipation of LWIP waves for $\vec{k} \perp \vec{B}_0$	120
3.4 Collision Frequencies	64	4.1.10 Oblique LWIP waves	121
3.4.1 The electron-ion collision frequency	64	4.2 Waves in Single Partially Ionized Fluid—the SPIF	124
3.4.2 The electron-electron collision frequency	66	4.3 Waves in Two-fluid Picture	126
3.4.3 The electron-neutral collision frequency	66	4.3.1 Incompressible wave-motions	126
3.4.4 The ion-neutral collision frequency	66	4.3.2 Compressible wave-motions	135
3.5 Equilibrium of the Three-fluid System	67	4.4 Electrostatic Waves in Three-fluid Picture	140
3.6 Hydrostatic Equilibrium	67	4.5 Electrostatic Waves in Magnetized Three-fluids	149
3.7 Hydrodynamic Equilibrium	69	4.6 Electromagnetic Waves in Three-fluids	161
3.8 Equilibrium with Collisional Forces	73	4.6.1 Electromagnetic waves in unmagnetized three-fluids	163
3.9 Equilibrium of Collisionally Dominated Fluids	76	4.7 Electromagnetic Waves in Magnetized Three-fluids	168
3.10 Three-fluid Equilibrium with Magnetic Field	78	4.7.1 Electromagnetic waves with $\vec{k} \perp \vec{B}_0$	170
3.11 Three-fluid Equilibrium with Magnetic and Collisional Forces	79	4.7.2 Electromagnetic waves with $\vec{k} \parallel \vec{B}_0$	176
3.12 Equilibrium in the Two-fluid Description of a Partially Ionized Plasma	83	4.8 Summary	181
3.12.1 Hydrostatic equilibrium	83	4.9 Problems	181
3.12.2 Hydrodynamic equilibrium	84	5 Advanced Topics in Partially Ionized Plasmas	184
3.13 Equilibrium in Collisionally Dominated Two-fluids	86	5.1 Equilibrium of Partially Ionized Structures in the Solar Atmosphere	184
3.14 Two-fluid Equilibrium with Magnetic Field	88	5.2 Equilibrium Plasma Structures with Hall Effect	186
3.14.1 With current density $\vec{J} = J_\theta$	92	5.3 Hall Equilibrium of the Weakly Ionized Plasmas	187
3.14.2 Current density $\vec{J} \parallel \vec{B}$	93	5.4 Hall Equilibrium of the Static Weakly Ionized Plasmas	188
3.15 Two-fluid Equilibrium with Collisional Forces	94	5.5 Dynamical Hall Equilibrium	189
3.16 Equilibrium of the SPIF	95	5.6 Static Equilibrium with Ambipolar and Resistive Effects	193
3.17 Equilibrium of the Weakly Ionized Plasma	95	5.7 Taylor Relaxation in Weakly Ionized Plasmas	194
3.18 Hall Equilibrium of the Weakly Ionized Plasmas	97	5.7.1 Taylor relaxation in a single-fluid	194
3.19 Summary	99	5.7.2 Taylor relaxation in an ideal single-fluid with flow	197
3.20 Problems	100	5.7.3 Taylor relaxation in a two-fluid system	197
4 Waves in Partially Ionized Plasmas	102	5.7.4 Taylor relaxation in a weakly ionized plasma	199
4.1 Waves in a Weakly Ionized Plasma	102	5.8 Hall Waves in Rotating Weakly Ionized Plasmas	201
4.1.1 Transverse waves in weakly ionized plasmas—the TWIP waves	107	5.9 Exact Non-linear Dispersion Relation	206

5.10 Kolmogorov Dissipation Scales in Weakly Ionized Plasmas	207
5.11 Generation of Magnetic Fields in Partially Ionized Plasmas	213
5.11.1 Mean-field dynamo	215
5.11.2 Mean-field dynamo in partially ionized plasma	221
5.11.3 Hall dynamo	222
5.11.4 Mean-field dynamo with ambipolar diffusion	225
5.11.5 Hall and ambipolar dynamo	228
5.11.6 Differential rotation-Hall-ambipolar dynamo	229
5.11.7 Magnetic transport via ambipolar diffusion	230
5.11.8 Stability analysis of ambipolar diffusion	232
5.11.9 Sweet-Parker current slab in a weakly ionized plasma	235
5.11.10 Parker-Sweet reconnection mechanism	235
5.11.11 Parker-Sweet current slab	237
5.12 Summary	241
5.13 Problems	242
6 Research Problems in Partially Ionized Plasmas	244
6.1 The Three-fluid Description	244
6.2 The Two-fluid Description	245
6.3 The Single-fluid Description	245
6.4 Weakly Ionized Plasma	245
6.5 The Equilibrium	245
6.6 Waves	246
6.7 Continuation of Studies in Chapter 5	246
<i>Supplementary Matter</i>	249
<i>Index</i>	259