
Table of Contents

	Page
Preface	i
Table of Contents	vii
Chapter 1 Introduction	1
1.1. Definition of Plasma	2
1.2. The SI Units and The Gaussian Units	2
1.3. Temperature in Units of °K and eV	8
1.4. Boltzmann Relation	10
1.5. Debye Shielding and Debye Length	11
1.5.1. Debye Shielding in the Electron Time Scale	11
1.5.2. Debye Shielding in the Ion Time Scale	12
1.6. Plasma Parameter	13
1.7. Plasma Frequency	14
1.8. Gyro Frequency and Gyro Radius (or Larmor Radius)	15
1.9. Collisions	16
Chapter 2 Deriving the Vlasov Equation From the Klimontovich Equation	19
2.1. Klimontovich Equation	19
2.2. Vlasov Equation	22
Chapter 3 Deriving the Fluid Equations From the Vlasov Equation	25
3.1. The Vlasov-Maxwell System	25
3.2. The Fluid Variables	27
3.3. The Fluid Equations	31
3.3.1. The Fluid Equations of the α th Species	31
3.3.2. The Two-Fluid Equations in the Convective-Time-Derivative Form	32
3.3.3. The One-Fluid Equations in the Conservative Form for Studying Nonlinear Wave in the MHD Plasma	35
3.3.3.1. The One-Fluid Variables	35
3.3.3.2. The One-Fluid Equations	36
3.3.4. The One-Fluid Equations in the Convective-Time-Derivative	41

	Form	
Chapter 4	Deriving the Vlasov Equation From the Liouville Equation	47
4.1.	Liouville Equation	47
4.2.	BBGKY Hierarchy	48
Chapter 5	Linear Waves in the Electron-Ion Two-Fluid Plasma	51
5.1.	How to Linearize the Nonlinear Plasma Equations	52
5.2.	Linear Plane Waves in Uniform Two-Fluid Plasma	54
5.3.	Dispersion Relations of High-Frequency Waves in a Uniform Two-Fluid Plasma	58
5.3.1.	High-Frequency Waves in Unmagnetized Plasma	65
5.3.2.	High-Frequency Waves in Magnetized Plasma With \mathbf{k} Parallel to \mathbf{B}_0	66
5.3.3.	High-Frequency Waves in Magnetized Plasma With \mathbf{k} Perpendicular to \mathbf{B}_0	69
5.4.	Dispersion Relations of Cross-Ion-Electron-Time-Scale Linear Wave Modes in Uniform Two-Fluid Plasma	77
5.4.1.	Pure Electrostatic Wave Modes	77
5.4.2.	Incompressible EM Waves	79
5.4.3.	Compressible EM Waves	81
Chapter 6	Linear Waves in the MHD Plasma	85
6.1.	Linearized Wave Equations in a Uniform Isotropic MHD Plasma	85
6.2.	Linear Wave Modes in the MHD Plasma	88
6.2.1.	Entropy Mode	89
6.2.2.	Alfvén Mode (or Intermediate Mode)	90
6.2.3.	Fast Mode and Slow Mode	91
6.2.4.	Friedrichs Diagrams of the Phase Velocity and Group Velocity of the MHD Waves	94
Chapter 7	Particle Motions With Multiple Time Scales	97
7.1.	Periodic Motions and Drift Motions of a Charged Particle	97
7.1.1.	$\mathbf{E} \times \mathbf{B}$ Drift	98
7.1.2.	Gravitational Drift	100
7.1.3.	Curvature Drift	100
7.1.4.	Gradient B Drift	102

7.2.	Fluid Drift	103
7.2.1.	Ions' Diamagnetic Drift	103
7.2.2.	Electrons' Diamagnetic Drift	104
7.2.3.	Diamagnetic Current Density	104
7.2.4.	Magnetization Current	105
7.3.	Drift Motion in Time-Dependent Fields	106
7.3.1.	Polarization Drift	106
7.3.2.	Ponderomotive Force	107
7.3.2.1.	Ponderomotive Force in a High-Frequency Non-uniform Longitudinal E-Field	107
7.3.2.2.	Ponderomotive Force in a High-Frequency Non-uniform EM Wave Field	108
Chapter 8	Equilibrium Solutions of the Vlasov Equation	113
8.1.	Characteristic Curves of a Partial Differential Equation	113
8.2.	Equilibrium Solutions of Time-Independent Vlasov-Maxwell Equations	114
Chapter 9	Electrostatic Linear Waves in the Vlasov Plasma	117
9.1.	Landau Contour	117
9.2.	Linear Dispersion Relations of Electrostatic Waves	126
9.3.	Landau Damping	128
9.4.	Nyquist Method	129
Chapter 10	Two-Stream Instability	137
Chapter 11	Linear Waves in the Vlasov Plasma	145
11.1.	Linear Waves in Field-Free Plasma ($\mathbf{E}_0 = 0$, $\mathbf{B}_0 = 0$)	146
11.2.	Linear Waves in Magnetized Plasma With Uniform Background \mathbf{B}_0	151
Appendix A	Static Electric Field and Magnetic Field	165
A.1.	General Solutions	165
A.2.	Solutions of Special Cases	166
Appendix B	Ohm's Law in One-Fluid Plasma	169
Appendix C	Frozen-in Flux	173

C.1.	Proof of Frozen-in Flux (Method 1)	173
C.2.	Proof of Frozen-in Flux (Method 2)	174
C.3.	Conservation of Circulation vs. Frozen-in Flux in MHD Plasma	175
C.4.	Equipotential Surface in MHD Plasma	177
Appendix D	Curvature Drift	179
Appendix E	Gradient B Drift	181
Appendix F	Deriving the Relativistic Vlasov Equation From the Relativistic Klimontovich Equation	183
F.1.	Relativistic Klimontovich Equation	183
F.2.	Relativistic Vlasov Equation	185
Appendix G	Functions of Complex Variable	187
G.1.	Analytic Function & Residue Theorem	187
G.2.	Branch Point and Riemann Surface	188
Appendix H	Special Functions for Studying Linear Waves in Kinetic Plasmas	191
H.1.	Bessel Function	191
H.1.1.	Definition of Bessel Function	191
H.1.2.	Generating Function of Bessel Function	191
H.1.3.	Recursion Relations of Bessel Function	192
H.2.	Error Function	193
H.3.	Plasma Dispersion Function	194
Index		199