

Contents

Part I Plasma Physics

1	Nature of Plasma	3
1.1	Introduction	3
1.2	Charge Neutrality and Landau Damping	5
1.3	Fusion Core Plasma	6
2	Plasma Characteristics	13
2.1	Velocity Space Distribution Function	13
2.2	Plasma Frequency. Debye Length	14
2.3	Cyclotron Frequency. Larmor Radius	15
2.4	Drift Velocity of Guiding Center	16
2.5	Magnetic Moment. Mirror Confinement	19
2.6	Coulomb Collision. Fast Neutral Beam Injection	21
2.7	Runaway Electron. Dreicer Field	27
2.8	Electric Resistivity. Ohmic Heating	28
2.9	Variety of Time and Space Scales in Plasmas	28
3	Magnetic Configuration and Particle Orbit	31
3.1	Maxwell Equations	31
3.2	Magnetic Surface	33
3.3	Equation of Motion of a Charged Particle	34
3.4	Particle Orbit in Axially Symmetric System	36
3.5	Drift of Guiding Center in Toroidal Field	38
3.5.1	Guiding Center of Circulating Particles	39
3.5.2	Guiding Center of Banana Particles	40
3.6	Orbit of Guiding Center and Magnetic Surface	42
3.7	Effect of Longitudinal Electric Field on Banana Orbit	43
3.8	Polarization Drift	45
4	Velocity Space Distribution Function and Boltzmann's Equation	47
4.1	Phase Space and Distribution Function	47
4.2	Boltzmann's Equation and Vlasov's Equation	48

5	Plasma as MHD Fluid	51
5.1	Magnetohydrodynamic Equations for Two Fluids	51
5.2	Magnetohydrodynamic Equations for One Fluid	53
5.3	Simplified Magnetohydrodynamic Equations	55
5.4	Magnetoacoustic Wave	58
6	Equilibrium	61
6.1	Pressure Equilibrium	61
6.2	Equilibrium Equation for Axially Symmetric Systems	63
6.3	Tokamak Equilibrium	67
6.4	Upper Limit of Beta Ratio	69
6.5	Pfirsch–Schlüter Current	70
6.6	Virial Theorem	71
7	Plasma Transport	75
7.1	Collisional Diffusion (Classical Diffusion)	77
7.1.1	Magnetohydrodynamic Treatment	77
7.1.2	A Particle Model	79
7.2	Neoclassical Diffusion of Electrons in a Tokamak	80
7.3	Fluctuation Loss. Bohm and Gyro-Bohm Diffusion. Convective Loss	83
7.4	Loss by Magnetic Fluctuation	89
8	Magnetohydrodynamic Instabilities	91
8.1	Interchange Instabilities	92
8.1.1	Interchange Instability	92
8.1.2	Stability Criterion for Interchange Instability. Magnetic Well	95
8.2	Formulation of Magnetohydrodynamic Instabilities	99
8.2.1	Linearization of Magnetohydrodynamic Equations ..	99
8.2.2	Energy Principle	102
8.3	Instabilities of a Cylindrical Plasma	104
8.3.1	Instabilities of Sharp-Boundary Configuration	104
8.3.2	Instabilities of Diffuse Boundary Configurations	109
8.3.3	Suydam’s Criterion	113
8.3.4	Tokamak Configuration	115
8.4	Hain–Lüst Magnetohydrodynamic Equation	117
8.5	Energy Integral of Axisymmetric Toroidal System	119
8.5.1	Energy Integral in Illuminating Form	119
8.5.2	Energy Integral of Axisymmetric Toroidal System ..	121
8.5.3	Energy Integral of High- n Ballooning Mode	126
8.6	Ballooning Instability	128
8.7	Eta-i Mode Due to Density and Temperature Gradient	133

9	Resistive Instabilities	137
9.1	Tearing Instability	137
9.2	Resistive Drift Instability	142
10	Plasma as Medium of Waves	147
10.1	Dispersion Equation of Waves in a Cold Plasma	148
10.2	Properties of Waves	152
10.2.1	Polarization and Particle Motion	152
10.2.2	Cutoff and Resonance	153
10.3	Waves in a Two-Component Plasma	153
10.4	Various Waves	158
10.4.1	Alfven Wave	158
10.4.2	Ion Cyclotron Wave and Fast Wave	159
10.4.3	Lower Hybrid Resonance	161
10.4.4	Upper Hybrid Resonance	162
10.4.5	Electron Cyclotron Wave	162
10.5	Conditions for Electrostatic Waves	164
11	Landau Damping and Cyclotron Damping	167
11.1	Landau Damping (Amplification)	167
11.2	Transit Time Damping	171
11.3	Cyclotron Damping	171
11.4	Quasi-Linear Theory of Evolution in the Distribution Function	174
12	Hot Plasma	177
12.1	Energy Flow	178
12.2	Ray Tracing	182
12.3	Dielectric Tensor of Hot Plasma	183
12.4	Wave Heating in the Ion Cyclotron Frequency Range	189
12.5	Lower Hybrid Heating	192
12.6	Electron Cyclotron Heating	196
12.7	Velocity Space Instabilities (Electrostatic Waves)	199
12.7.1	Dispersion Equation of Electrostatic Wave	199
12.7.2	Electron Beam Instability	201
12.7.3	Various Velocity Space Instabilities	202
12.8	Derivation of Dielectric Tensor in Hot Plasma	202
12.8.1	Formulation of Dispersion Relation in Hot Plasma ..	202
12.8.2	Solution of Linearized Vlasov Equation	204
12.8.3	Dielectric Tensor of Hot Plasma	206
12.8.4	Dielectric Tensor of Bi-Maxwellian Plasma	209
12.8.5	Dispersion Relation of Electrostatic Wave	210

13	Instabilities Driven by Energetic Particles	215
13.1	Fishbone Instability	215
13.1.1	Formulation	215
13.1.2	MHD potential Energy	216
13.1.3	Kinetic Integral of Hot Component	218
13.1.4	Growth Rate of Fishbone Instability	221
13.2	Toroidal Alfvén Eigenmode	224
13.2.1	Toroidicity-Induced Alfvén Eigenmode	225
13.2.2	Instability of TAE Driven by Energetic Particles	229
13.2.3	Various Alfvén Modes	237
14	Computer Simulation	239
14.1	MHD model	240
14.2	Linearized Kinetic Model	242
14.3	Modeling Bulk Plasma and Energetic Particles	243
14.4	Gyrofluid/Gyro-Landau-Fluid Models	244
14.5	Gyrokinetic Particle Model	247
14.6	Full Orbit Particle Model	251

Part II Controlled Nuclear Fusion

15	Development of Fusion Research	259
15.1	From Secrecy to International Collaboration	260
15.2	Artsimovich Era	262
15.3	The Trek to Large Tokamaks Since the Oil Crisis	263
15.4	Alternative Approaches	266
16	Tokamaks	269
16.1	Tokamak Devices	269
16.2	Equilibrium	272
16.3	MHD Stability and Density Limit	274
16.4	Beta Limit of Elongated Plasma	277
16.5	Impurity Control, Scrape-Off Layer and Divertor	278
16.6	Confinement Scaling of L Mode	284
16.7	H Mode and Improved Confinement Modes	286
16.8	Non-Inductive Current Drive	293
16.8.1	Lower Hybrid Current Drive	293
16.8.2	Electron Cyclotron Current Drive	297
16.8.3	Neutral Beam Current Drive	300
16.8.4	Bootstrap Current	302
16.9	Neoclassical Tearing Mode	304
16.10	Tokamak Reactors	311

17 RFP Stellarator	319
17.1 Reversed Field Pinch	319
17.1.1 Reversed Field Pinch Configuration.....	319
17.1.2 MHD Relaxation	320
17.1.3 Confinement	323
17.1.4 Oscillating Field Current Drive	325
17.2 Stellarator	325
17.2.1 Helical Field	325
17.2.2 Stellarator Devices	329
17.2.3 Neoclassical Diffusion in Helical Field	331
17.2.4 Confinement of Stellarator System.....	334
18 Inertial Confinement	337
18.1 Pellet Gain	337
18.2 Implosion	341
18.3 MHD Instabilities	345
18.4 Fast Ignition	347
References	353
Index	367



<http://www.springer.com/978-3-540-24217-8>

Plasma Physics and Controlled Nuclear Fusion

Miyamoto, K.

2005, XI, 372 p., Hardcover

ISBN: 978-3-540-24217-8