

Contents

Preface	ix
---------	----

Preface to English Edition	xv
----------------------------	----

Chapter 8. Non-linear Waves in a Collisionless Plasma

8.1. Non-linear high-frequency waves in a cold plasma	
8.1.1. Non-linear non-relativistic Langmuir oscillations	1
8.1.2. Equations describing non-linear waves in a relativistic plasma when there are no thermal effects	3
8.1.3. Longitudinal waves in a relativistic plasma	7
8.1.4. Transverse waves in a relativistic plasma	8
8.1.5. Coupled longitudinal-transverse waves in a relativistic plasma	11
8.2. Non-linear waves in an unmagnetized two-temperature plasma	
8.2.1. Equations describing a non-linear wave in a quasi-equilibrium plasma	14
8.2.2. Simple (Riemann) waves	16
8.2.3. Periodic and solitary waves	19
8.2.4. Quasi-shock waves	22
8.3. Non-linear waves in an unmagnetized non-equilibrium plasma	
8.3.1. Equations describing a non-linear wave in a non-equilibrium plasma	24
8.3.2. Simple waves	25
8.3.3. Stationary waves	27
8.3.4. Multiple-current flow in a non-equilibrium plasma	30
8.4. Non-linear waves in a magneto-active plasma with hot electrons	
8.4.1. Equations describing a non-linear wave in a plasma in a magnetic field	35
8.4.2. Simple magneto-sound waves	37
8.4.3. Stationary magneto-sound waves	38
8.5. Non-linear low-frequency waves in a cold plasma in a magnetic field	
8.5.1. Equations describing a non-linear wave in a cold magneto-active plasma	41
8.5.2. Non-linear waves for the case of a strong magnetic field	43
8.5.3. Non-linear waves in the case of a weak magnetic field	44

Chapter 9. Theory of Plasma Oscillations in the Quasi-linear Approximation

9.1. Quasi-linear theory of the oscillations of an unmagnetized plasma	
9.1.1. The quasi-linear approximation	47
9.1.2. Quasi-linear relaxation	53
9.1.3. Relaxation of one-dimensional wavepackets	54
9.1.4. Effect of the Coulomb collisions on the quasi-linear relaxation and Landau damping of the Langmuir oscillations	57
9.2. Quasi-linear theory of the oscillations of a magneto-active plasma	
9.2.1. Basic equations	59
9.2.2. Quasi-linear relaxation in a magneto-active plasma	67
9.2.3. Relaxation of one-dimensional wavepackets in a magneto-active plasma	72
9.2.4. Effect of collisions on quasi-linear relaxation and Cherenkov and cyclotron damping of oscillations	77

CONTENTS

Chapter 10. Non-linear Wave-Particle Interactions

10.1.	Kinetic equations for the waves	
10.1.1.	Non-linear equations for the wave amplitude	82
10.1.2.	Equation for the correlation function	85
10.1.3.	Three-wave processes and non-linear Landau damping	88
10.2.	Turbulent processes in which Langmuir waves take part	
10.2.1.	Interaction between Langmuir waves and ion-sound waves	90
10.2.2.	Decay instability of Langmuir waves	92
10.2.3.	Non-linear damping of Langmuir waves	95
10.3.	Ion-sound turbulence	
10.3.1.	Non-linear damping of ion sound	99
10.3.2.	Stationary distributions of turbulent waves	103
10.4.	Interaction between magneto-sound and Alfvén waves	
10.4.1.	The collision integral and the H -theorem for the gas of plasmons	106
10.4.2.	The Hamiltonian of a system of plasmons	108
10.4.3.	Probabilities for three-plasmon processes	111
10.4.4.	Plasmon lifetimes	113

Chapter 11. Fluctuations in a Plasma

11.1.	Fluctuation-Dissipation relation	
11.1.1.	Space-time correlation functions	116
11.1.2.	The spectral density of fluctuations and the energy dissipation in a medium	117
11.1.3.	Symmetry of the response tensor	121
11.2.	Electromagnetic fluctuations in an equilibrium plasma	
11.2.1.	Electromagnetic fluctuations in media with space-time dispersion	122
11.2.2.	Electromagnetic fluctuations in an isotropic plasma	125
11.2.3.	Charge density fluctuations	126
11.2.4.	Current density fluctuations	130
11.2.5.	Electromagnetic field fluctuations	131
11.2.6.	Electron and ion density fluctuations	131
11.2.7.	Fluctuations in a plasma in a magnetic field	132
11.3.	Inversion of the fluctuation-dissipation relation	
11.3.1.	Connection between the dielectric permittivity of the plasma and the correlation function of the fluctuations for a system of non-interacting particles	134
11.3.2.	Dielectric permittivity of an isotropic plasma	136
11.3.3.	Dielectric permittivity tensor of a plasma in a magnetic field	137
11.4.	Electromagnetic fluctuations in a non-isothermal plasma	
11.4.1.	Fluctuations in an isotropic non-isothermal plasma	139
11.4.2.	Fluctuations in an anisotropic non-isothermal plasma	142
11.4.3.	Fluctuations in a non-isothermal plasma in a magnetic field	143
11.5.	Electromagnetic fluctuations in a non-equilibrium plasma	
11.5.1.	Spectral densities of fluctuations in a plasma with non-equilibrium, but stable distribution functions	144
11.5.2.	Collective fluctuations and effective temperature	147
11.5.3.	Critical fluctuations near the boundaries of plasma instability	149
11.5.4.	Fluctuations in a non-equilibrium plasma in a magnetic field	152
11.6.	Kinetic theory of fluctuations	
11.6.1.	Fluctuations in the distribution function	154
11.6.2.	Fluctuations in the distribution functions in a non-isothermal plasma	158
11.6.3.	Evolution in time of the fluctuations	160
11.6.4.	Fluctuations in a plasma-beam system	163
11.6.5.	Effect of particle collisions on fluctuations in a plasma	163
11.6.6.	Transition to the hydrodynamical theory of fluctuations	168
11.7.	Fluctuations in a partially ionized plasma in an external electrical field	
11.7.1.	Fluctuations when there is no magnetic field	170
11.7.2.	Critical fluctuations in electrical and magnetic fields	172

CONTENTS

Chapter 12. Scattering and Transformation of Waves in a Plasma

12.1.	Scattering of electromagnetic waves in an unmagnetized plasma	
12.1.1.	Scattering current	175
12.1.2.	Scattering cross-section	180
12.1.3.	Spectral distribution of the scattered radiation	182
12.1.4.	Critical opalescence	184
12.2.	Transformation of transverse and longitudinal waves in a plasma	
12.2.1.	Transformation of a transverse wave into a longitudinal one	185
12.2.2.	Transformation and scattering of longitudinal waves	187
12.2.3.	Spontaneous emission by a non-equilibrium plasma	190
12.3.	Incoherent reflection of electromagnetic waves from a plasma	
12.3.1.	Reflection coefficient	192
12.3.2.	Spectral distribution of the reflected emission	195
12.4.	Scattering and transformation of waves in a plasma in a magnetic field	
12.4.1.	Field of the scattered waves; scattering and transformation cross-sections	197
12.4.2.	Scattering and transformation of electromagnetic waves by incoherent fluctuations	199
12.4.3.	Scattering and transformation of electromagnetic waves by resonance fluctuations	201
12.4.4.	Scattering and transformation of Langmuir waves	204
12.4.5.	Transformation of low-frequency waves by Langmuir fluctuations	206
12.5.	Scattering and transformation of waves in a partially ionized plasma in an external electrical field	
12.5.1.	Scattering of transverse waves when there is no external magnetic field	207
12.5.2.	Scattering of transverse waves when there is an external magnetic field present	209
12.5.3.	Critical opalescence when longitudinal waves are scattered or transformed	212
12.6.	Scattering and transformation of waves in a turbulent plasma	
12.6.1.	Transformation of longitudinal into transverse waves	216
12.6.2.	The scattering of electromagnetic waves by turbulent ion-sound oscillations	219
12.6.3.	Scattering of electromagnetic waves by turbulent high-frequency oscillations	222
12.7.	Echoes in a plasma	
12.7.1.	Undamped oscillations of the distribution function and echo effects in a plasma	223
12.7.2.	Longitudinal field echo oscillations	225
12.7.3.	Echo when the wavevectors of the perturbations are antiparallel	228

Chapter 13. Scattering of Charged Particles in a Plasma

13.1.	The passage of charged particles through an unmagnetized plasma	
13.1.1.	The field of a charge in a plasma	231
13.1.2.	Polarization energy losses when a charged particle moves through the plasma	232
13.1.3.	Change in the energy of a moving charge, caused by the fluctuations of the field in the plasma	237
13.1.4.	Scattering probability and energy losses of a particle	241
13.2.	Dynamic friction and diffusion coefficients in a plasma	
13.2.1.	The Fokker-Planck equation for test particles	249
13.2.2.	Dynamic friction and diffusion coefficients in an electron plasma	251
13.2.3.	Friction and diffusion coefficients in a two-temperature plasma	253
13.3.	Passage of charged particles through an equilibrium plasma in a magnetic field	
13.3.1.	Scattering probability in a magneto-active plasma	255
13.3.2.	Polarization energy losses of a particle, caused by the interaction with the longitudinal field	256
13.3.3.	Taking the curvature into account	258
13.3.4.	Cherenkov emission of a charge moving in a plasma in a magnetic field	259
13.4.	The interaction of charged particles with a non-equilibrium plasma	
13.4.1.	Scattering of charged particles by critical fluctuations	264
13.4.2.	Interaction of charged particles with a turbulent plasma	268
13.4.3.	Interaction of charged particles with a turbulent plasma in a magnetic field	278
	References	283
	Glossary	295
	Index	299