



# Contents

<b>1. Introduction</b> .....	<b>1</b>
------------------------------	----------

---

## **Part I Classical Theory**

---

<b>2. Free Charged Particles and a Field</b> .....	<b>8</b>
2.1 The Equations of Particle Motion. Local Field .....	8
2.2 The Equations for Microscopic Field Strengths (Lorentz Equations)	9
2.3 A Coulomb Plasma .....	13
2.4 The Complete Set of Microscopic Equations for a Plasma .....	14
2.5 The Equation of Motion of Free Charged Particles and Field Oscillators .....	14
2.6 Lagrange Function .....	17
2.7 Hamiltonian Function .....	18
2.8 The Equations of Motion for Phase Densities of Particles and Field Oscillators .....	19
2.9 Distribution Functions of Particles and Field Oscillators .....	21
2.10 Chain of Equations for Distribution Functions of Particles and Field Oscillators .....	23
2.11 Equations for Moments .....	25
2.12 The Relation Between Moments and Distribution Functions .....	27
<b>3. Atoms and Field</b> .....	<b>30</b>
3.1 The Equations of Motion of Pairs of Free Charged Particles and Atoms .....	30
3.2 The Equations for Microscopic Phase Density of Atoms .....	33
3.3 Microscopic Field Equations .....	36
3.4 Lagrange Function .....	42
3.5 Hamiltonian Function .....	45
3.6 The Closed Equation for Phase Density of Atoms .....	48
3.7 The Interaction of Atoms .....	49
3.8 Atoms and Field Oscillators .....	50
3.9 The Method of Distribution Functions for a System of Atoms and Field Oscillators .....	54
<b>4. The Kinetic Equations for a System of Free Charged Particles and a Field</b> .....	<b>56</b>
4.1 The Principal Parameters (Free Charged Particles) .....	56



4.2	Principal Parameters for a System of Atoms .....	58
4.2.1	Interaction Parameters .....	58
4.2.2	The Relaxation Processes Parameters for Atoms .....	59
4.2.3	Comparison of the Density Parameters $\varepsilon_d$ and $\varepsilon_{em}$ .....	61
4.3	First Moments Approximation .....	62
4.4	The Kinetic Equations for a Coulomb Plasma .....	65
4.5	Electromagnetic Interaction in the Kinetic Equations of a Plasma	70
4.6	The Polarization Approximation for the System of Charged Particles and Field Oscillators .....	73
4.7	The Equilibrium Fluctuations of an Electromagnetic Field .....	78
4.8	The Kinetic Theory of Fluctuations .....	81
4.9	Nonequilibrium Fluctuations of the Field .....	89
<b>5.</b>	<b>Brownian Motion .....</b>	<b>93</b>
5.1	The Langevin Equations .....	93
5.2	The Fokker – Planck Equation .....	94
5.3	Diffusion of Brownian Particles .....	97
5.4	The Brownian Motion of a Harmonic Oscillator. The Nyquist Formula .....	99
5.5	Nondissipative Nonlinearity. Brownian Motion at Phase Transitions .....	100
5.5.1	Fokker – Planck and Einstein – Smoluchowsky Equations	100
5.5.2	The Equilibrium Distribution .....	101
5.5.3	Energy Fluctuations .....	103
5.5.4	Self-Consistent Approximation with Respect to Energy ...	104
5.5.5	The Order Parameter .....	105
5.5.6	Fluctuations of the Order Parameter .....	106
5.6	Spectral Distribution of the Mean Energy .....	107
5.7	The Response of the System to External Factors .....	108
5.7.1	Dynamic Response. Spectral of Fluctuations .....	110
5.7.2	The Critical Region .....	111
5.8	Phase Transition in a Distributed System .....	111
5.8.1	A Langevin Source in the Ginzburg – Landau Equation ..	111
5.8.2	The Landau Theory .....	113
5.8.3	Fluctuations of the Order Parameter .....	113
5.8.4	Spatial Correlations .....	114
5.8.5	Extrapolation of Landau Theory into the Critical Region .	116
5.8.6	Critical Indices .....	117
5.8.7	Coordination of Limit Transitions .....	118
5.8.8	The Critical Point .....	120
5.8.9	The Region of Scale Invariance .....	120
5.8.10	The Transition to the Results of Landau Theory .....	121
5.8.11	Correlation Times and Spectrum Widths at a Phase Transition .....	122
5.9	Dissipative Nonlinearity .....	125
5.10	The Langevin Equations for a Self-Oscillatory System. The Fokker – Planck Equation .....	127



5.11	The Stationary Distribution of the Energy of Oscillations .....	131
5.12	Fluctuations of Amplitude. Diffusion of a Phase .....	133
5.13	Spectral Distribution of the Energy of Autooscillations .....	135
5.14	The Response to Resonant Force .....	139
5.15	Kinetic Theory of Fluctuations in Brownian Motion .....	143
<b>6.</b>	<b>Kinetic Equations for an Atom – Field System .....</b>	<b>147</b>
6.1	Electromagnetic Fluctuations in a Gas .....	147
6.2	The Kinetic Equation. The Collision Integral .....	152
6.3	The Equation for the Polarization Vector .....	157
6.4	The Effective Lorentz Field .....	161
6.5	Dissipative Processes Due to Close Correlations .....	163
6.6	The Equation for the Polarization Vector .....	165
6.7	The Dielectric Permittivity. The Lorentz – Lorenz Formula. The Equation of Dispersion .....	167
6.8	Fluctuations of Polarization and Field at Above-Critical Temperatures .....	170
6.9	Phase Transition in an Atom – Field System .....	173
6.9.1	Initial Equations .....	173
6.9.2	Fluctuations of the “Source” $\delta P^{\text{source}}$ .....	175
6.9.3	Induced Fluctuations of the Polarization Vector .....	176

---

## Part II Quantum Theory

---

<b>7.</b>	<b>Microscopic Equations .....</b>	<b>180</b>
7.1	A System of Free Charged Particles with Coulomb Interaction ...	180
7.2	Partially Ionized Plasma .....	184
7.3	The Hamiltonian with Electromagnetic Interaction (Extreme Cases)	188
7.4	The Equations for Operators of Field and Particles .....	189
7.5	Operator Equations for an Atom – Field System in Dipole Approximation .....	191
<b>8.</b>	<b>The Kinetic Equations for Partially Ionized Plasma. The Coulomb Approximation .....</b>	<b>194</b>
8.1	The Polarization Approximation .....	194
8.2	The Correlation of the Source Fluctuations .....	196
8.3	Dielectric Permittivity .....	199
8.4	The Spectral Density of the Electric Field Fluctuations .....	205
8.5	The Collision Integral .....	207
8.6	The Structure of Collision Integrals .....	209
8.7	The Equations for Concentrations .....	213
8.8	The Kinetic Theory of Fluctuations in Partially Ionized Plasma ..	215
<b>9.</b>	<b>Kinetic Equations for Partially Ionized Plasma. The Processes Conditioned by a Transverse Electromagnetic Field .....</b>	<b>220</b>
9.1	Dielectric Permittivity .....	220



9.2	The Spectral Density of Transverse Field Fluctuations .....	222
9.3	The Collision Integral .....	223
9.4	The Structure of the Collision Integrals for the Transparency Region .....	225
9.5	The Evolution of the Distribution Function of Atoms .....	226
9.6	The Equations for Concentrations of Free Charged Particles and Atoms. The Contribution from the Interaction of Particles and Waves .....	230
9.7	Cooling and Heating of Atoms by Resonant Field. Classical Theory .....	232
9.8	Cooling and Heating of Atoms by a Resonant Field. Quantum Theory .....	235
<b>10.</b>	<b>Spectral Emission Line Broadening of Atoms in Partially Ionized Plasma .....</b>	<b>238</b>
10.1	The Foundations of the Kinetic Theory of Spectral Line Broadening .....	238
10.2	The Dissipative Matrix. The Frequency Shift .....	243
10.3	The Influence of the Source Fluctuations on Linewidth and Frequency Shift .....	245
10.4	The Probabilities of the Transition. The Broadening at Spontaneous and Induced Processes .....	247
10.5	Spectral Line Broadening by a Plasma's Electrons .....	250
10.6	Resonant Broadening of Spectral Lines Due to Atoms' Collisions .....	253
10.7	Spectral Line Broadening upon Elastic Collisions of Atoms ...	255
10.8	Radiation Capture (Inprisonment of Radiation) .....	259
10.9	The Influence of the Static Electric Field upon the Atomic Emission Spectrum .....	263
10.10	The Distribution of Microfields Created by Ions. The Holzmark Formula .....	265
10.11	The Atomic Emission Spectrum with the Ion Field Distribution Taken into Account .....	267
10.12	The Influence of an Electron Field on the Intensity Distribution at the Wings of the Spectral Line .....	270
10.13	Taking Strong Short-Range Interactions and Collective Long-Range Interactions into Account Simultaneously .....	271
10.14	Some Problems of the Kinetic Theory of Spectral Line Broadening .....	272
<b>11.</b>	<b>Fluctuations and Kinetic Processes in Systems Composed of Strongly Interacting Particles .....</b>	<b>275</b>
11.1	The Influence of the Correlations of Atoms' Positions on Their Spontaneous Radiation .....	275
11.2	The Effective Lorentz Field .....	277
11.3	The Influence of the Correlations of Atoms' Positions on the Coefficient of Spontaneous Emission .....	278
11.4	The Kubo and the Callen – Welton Equations .....	280



11.5	Fluctuations of the Distribution Function of the Density Matrix. The Random Source in the Liouville Equation . . . . .	286
11.6	Fluctuations in an Extended System. The Polarization Approximation . . . . .	288
11.7	The Fluctuations of Polarization and Field. The Callen – Welton Equation for Nonequilibrium States . . . . .	290
11.8	The Kinetic Equation Giving the Distribution Function for the States of a System of Interacting Atoms . . . . .	294
11.9	The Transition to the Kinetic Equation for One-Particle Distribution Functions of Atoms . . . . .	298
11.10	The Transparency Region. Probabilities of Transition . . . . .	300
11.11	The Distribution Function of a System of Atoms and Mean Field. The First-Moments Approximation . . . . .	301
11.12	The Influence of the Correlations of Atoms' Positions on the Absorption and Scattering of Electromagnetic Waves . . . . .	302
<b>12.</b>	<b>Fluctuations in Quantum Self-Oscillatory Systems . . . . .</b>	<b>305</b>
12.1	A System Composed of Two-Level Atoms and a Field . . . . .	305
12.2	Stationary Generation Regime, Without Taking Fluctuations into Account . . . . .	308
12.3	Sources of Fluctuations in a Quantum Generator . . . . .	310
12.4	Field Equations with Fluctuations Taken into Account . . . . .	313
12.5	Fluctuations of Radiation in a Quantum Optical Generator . . . . .	315
12.6	Spatial and Temporal Correlations of a Field Below the Generation Threshold . . . . .	318
12.7	Spatial and Temporal Correlations of the Fluctuations of Laser Radiation . . . . .	320
<b>13.</b>	<b>Phase Transitions in a System Composed of Atoms and a Field . . . . .</b>	<b>324</b>
13.1	A Phase Transition in a System Composed of Two-Level Atoms and a Field . . . . .	324
13.2	Fluctuations in the Polarization and the Field at Above-Critical Temperatures . . . . .	327
13.3	Fluctuations in the Polarization and the Field in the Critical Region . . . . .	329
13.3.1	The Equation for the Polarization Vector . . . . .	329
13.3.2	Induced Fluctuations of Polarization . . . . .	331
13.3.3	Field Fluctuations . . . . .	332
13.4	Laser-Radiation-Induced Phase Transitions in a System of Two-Level Atoms . . . . .	333
13.5	The Influence of a Phase Transition on Generation . . . . .	338
13.5.1	In Ferroelectrics . . . . .	338
13.5.2	In Liquid Crystals . . . . .	342
<b>14.</b>	<b>Conclusion . . . . .</b>	<b>347</b>
	<b>References . . . . .</b>	<b>349</b>
	<b>Subject Index . . . . .</b>	<b>361</b>