Contents

PART I. CLASSICAL SYSTEMS

1. The General Diagram Method for Classical Gases . 1

1. Distribution Functions and the Liouville Equation 1
2. The Fourier Transforms of the Distribution Functions and the Macroscopic Specification of Physical Systems 8
3. Size and Shape of Fourier Components at Time Zero 19
4. The Green's Function and the Formal Solution of the Liouville Equation. 26
5. Perturbation Theory 33
6. The Diagram Technique 41
7. Orders of Magnitude of Diagrams 45
8. Reduced Distribution Functions at Time t 47

2. The Short-Time Behavior of Classical Plasmas — The Vlassov Equation. 55

9. General Discussion of the Properties of Classical Plasmas 55
10. Choice of Diagrams for Short Times 60
11. Derivation of the Vlassov Equation 65
12. Some General Properties of the Vlassov Equation . 69

3. The Theory of Plasma Oscillations 73

13. The Solution of the Initial-Value Problem for the Linearized Vlassov Equation 73
14. Individual Particle Behavior and Collective Bevior 76
15. Individual Particle Behavior 80
16. The "Collective" Behavior 83
17. The Overall Behavior of the Plasma. 86

4. The Dispersion Equation 89

18. The Dielectric Constant of the Plasma. 89
19. The Stability Criterion. 95
20. Limiting Forms of the Dispersion Equation . . . 101
21. The Dielectric Constant for a Maxwellian Distribution 108
22. An Example of an Unstable Distribution. 112

5. The van Kampen-Case Treatment of the Vlassov Equation 117

23. Eigenfunctions of the Vlassov Operator 117
24. Eigenfunctions of the Adjoint Vlassov Operator. . 120

25. Completeness of the Set of Vlassov Eigenfunctions 122
26. Application of the Eigenvalue Expansion to the Solution of the Initial-Value Problem 126

6. The Long-Time Behavior of Classical Plasmas . . . 129
27. General Structure of the Perturbation Series for Long Times 129
28. The Cycle Diagram in the Case of a Plasma . . . 133
29. Choice of Contributions for a Plasma 140

7. The Landau ("Fokker–Planck") Approximation . . 146
30. Evolution of the Velocity Distribution Function . 146
31. The Concept of Pseudo-Diagonal Fragments . . . 151
32. The Evolution of $\rho_{\mathbf{k}}(\alpha; t)$ and of $f(\alpha; t)$ 156
33. The Boltzmann Equation and its Relation to the Landau Equation 162

8. Properties of the Landau Equation 170
34. Irreversibility and the H-Theorem 170
35. Explicit Form of the Landau Equation 174
36. The Hydrodynamic Equations 178
37. The Fokker-Planck Equation 181
38. Connection with the Theory of Brownian Motion . 186

9. The Ring Approximation 192
39. The Ring Diagrams 192
40. Summation of the Rings 198
41. Solution of the Integral Equation for Plasmas. (Imaginary Part of F) 201
42. Inhomogeneous Systems 207

10. Binary Correlations in the Ring Approximation . . 210
43. Preliminary Discussion of the Diagrams 210
44. Summation of the Creation Diagrams 216
45. Solution of the Integral Equation for Plasmas. (Real Part of F) 220

11. The General Description of a Plasma in the Ring Approximation 223
46. General Properties of the Kinetic Equation. . . . 223
47. Connection between Correlation Function and Kinetic Equation 226
48. Connection between the Ring Equation and the Landau Equation 229
49. Brownian Motion in the Ring Approximation. . . 233
50. Limitations of the Ring Approximation 238

12. The Equilibrium State 242
51. Correlations in Equilibrium. 242
52. Summation of Creation Diagrams in Equilibrium . 245
53. Thermodynamics of a Plasma in Equilibrium . . . 247
54. Mayer's Theory 250

13. Non-Equilibrium Stationary States and the Theory of Transport Coefficients 257
55. Free Relaxation and Forced Relaxation 257
56. Traditional Theories of Transport Coefficients . . 259
57. A General Formula for the Electric Current . . . 268
58. Existence and Stability of a Stationary State . . . 274
59. Stationary State vs. Kinetics of Approach 277
60. The Perfect Lorentz Gas 280

PART II. QUANTUM-STATISTICAL SYSTEMS

14. The General Diagram Method for Quantum Gases 287
61. The Density Matrix and the Wigner Distribution Function 287
62. The Fourier Transform of the Wigner Function . . 294
63. The Equation of Evolution of the Fourier Components of the Wigner Function 303
64. The Limit of Boltzmann Statistics and the Classical Limit 309
65. The Quantum-Statistical Diagram Technique . . . 312

15. Short-Time Behavior of Quantum Plasmas and the Quantum Vlassov Equation 316
66. The Choice of Diagrams 316
67. Derivation and Solution of the Linear Quantum Vlassov Equation 321
68. General Features of the Quantum Vlassov Description 323
69. The Stability Condition for Quantum-Statistical Systems 325
70. The Quantum Dielectric Constant for an Electron Gas at Zero Temperature 328

16. Long-Time Behavior of Quantum Plasmas — The Cycle Approximation 335
71. Choice of Diagrams 335
72. The Quantum-Mechanical Cycle Diagram 336
73. The Quantum "Cycle" Equation 340
74. General Properties of the Cycle Equation 342
75. Motion of a Test Particle in an Electron Gas at Zero Temperature 345

17. The Quantum-Statistical Ring Approximation . . . 353
76. The Quantum-Statistical Ring Diagrams 353
77. Derivation of the Kinetic Equation 356
78. Collective Effects in the Motion of a Test Particle through an Electron Gas at Zero Temperature . . 359

18. Binary Correlations and the Equilibrium State for an Electron Gas 367
79. The Density Correlation Function 367
80. Eigenvalues and Eigenfunctions of the Kernel $G_k(|\tau|)$ 372
81. The Ground-State Energy of an Electron Gas . . . 375

Appendices

1. Properties of the Laplace Transformation 385
2. The Cauchy Integral 390
3. Orthogonality Properties of Vlassov Eigenfunctions 406
4. Derivation of a General Type of Kinetic Equation. 408
5. Miscellaneous Theorems Concerning Normal Products of Creation and Destruction Operators 411
6. Derivation of the Quantum-Statistical Liouville Equation 415
7. Proof of Equation (81.1) 417
8. Non-markoffian Kinetic Equation for a Stable Classical Plasma 419
9. Kinetic Equation for Unstable Classical Plasmas . 431
10. An Alternative Summation Method for the Ring Diagrams 445
11. The Kinetic Equation for a Plasma in a Strong External Field 453

Symbol Index 463

Author Index 469

Subject Index 473