

Contents

1.	Introduction	1
2.	Physical Concepts and Exact Results	4
2.1.	Basic Concepts for Coulomb Systems	4
2.2.	Survey of Exact Quantum-Mechanical Results for Coulomb Systems	12
2.3.	Survey of Exact Quantum-Statistical Results for Macroscopic Coulomb Systems	16
3.	Quantum Statistics of Many-Particle Systems	22
3.1.	Elements of Quantum Statistics	22
3.1.1.	Quantum Mechanics of Many-Particle Systems	22
3.1.2.	The Method of Second Quantization	24
3.1.3.	Quantum Statistics. Density Operator	26
3.1.4.	Reduced Density Operators. Bogolyubov Hierarchy	29
3.1.5.	The Classical Limit, BBGKY Hierarchy	31
3.1.6.	Systems in Thermodynamical Equilibrium	32
3.2.	The Method of Green's Functions in Quantum Statistics	35
3.2.1.	Definition of Green's Functions	35
3.2.2.	General Properties of the Correlation Function and One-Particle Green's Function	38
3.2.3.	Long Time Behaviour of Correlation Functions	43
3.2.4.	Equation of Motion for the One-Particle Green's Function. Self Energy	45
3.2.5.	Dynamical and Thermodynamical Information Contained in the Spectral Function $A(p, \omega)$	49
3.2.6.	The Two-Particle Green's Function	52
3.2.7.	Equation of Motion for Higher Order Green's Functions	55
3.2.8.	The Binary Collision Approximation (Ladder Approximation)	61
3.2.9.	T -Matrix and Thermodynamic Properties in Binary Collision Approximation	66
3.3.	Quantum Statistics of Charged Many-Particle Systems	71
3.3.1.	Basic Equations. Screening	71
3.3.2.	Analytic Properties of V^s and Π	75
3.3.3.	The "Random Phase Approximation" RPA	77
4.	Application of the Green's Function Technique to Coulomb Systems	80
4.1.	Types of Different Approximations	80
4.1.1.	Diagram Representation of Σ and Π	80
4.1.2.	The RPA and the V^s -Approximation for the Self Energy	82
4.1.3.	Many-Particle Complexes and T -Matrices	84

4.1.4.	Cluster Formation and the Chemical Picture	85
4.1.5.	Cluster Decomposition of the Self Energy	86
4.2.	Dielectric Properties of Charged Particle Systems. Random Phase Approximation	87
4.2.1.	Linear Response to External Perturbations. General Remarks	87
4.2.2.	Properties of the RPA Dielectric Function	94
4.2.3.	Plasma Oscillations (Plasmons)	101
4.3.	Single-Particle Excitations	111
4.3.1.	Quasi-Particle Concept	111
4.3.2.	Self Energy in V^s -Approximation	113
4.4.	Two-Particle Properties in a Plasma	118
4.4.1.	Bethe-Salpeter Equation for a Two-Particle Cluster	118
4.4.2.	Solution of the Bethe-Salpeter Equation. Effective Wave Equation and Spectral Representations	121
4.4.3.	Two-Particle States in the Dynamically Screened Ladder Approximation . .	124
4.4.4.	Two-Particle States in Surrounding Medium in First Born Approximation .	126
4.4.5.	Numerical Results and Discussion of the Two-Particle States	130
4.5.	Dielectric Function Including Bound States	137
4.5.1.	Extended RPA Dielectric Function for a Partially Ionized Plasma	137
4.5.2.	Limiting Behaviour of the Extended RPA Dielectric Function	141
4.5.3.	Self Energy and Vertex Corrections to the Extended RPA Dielectric Function	144
4.5.4.	Local Field Effects and Enhancement of the Dielectric Function	146
5.	Equilibrium Properties in Classical and Quasiclassical Approximation	150
5.1.	The One-Component Plasma Model	150
5.2.	Many-Component Systems. Slater Sums	154
5.2.1.	Partition Functions and Effective Potentials	154
5.2.2.	Calculation of Slater Sums and Effective Potentials	157
5.3.	The Pair Distribution Function	161
5.3.1.	Basic Equations and Hierarchy	161
5.3.2.	Discussion of the Pair Distribution	163
5.4.	Thermodynamic Functions	165
5.4.1.	Cluster Expansions of the Free Energy	165
5.4.2.	Density Expansions of the Free Energy	166
6.	Quantum-Statistical Calculations of Equilibrium Properties	170
6.1.	Equation of State in the Screened Ladder Approximation	170
6.1.1.	The Second Virial Coefficient	170
6.1.2.	Evaluation of the Higher Order Contributions	172
6.1.3.	Evaluation of the Hartree-Fock and the Montroll-Ward Contributions . .	176
6.2.	Density and Chemical Potential in the Screened Ladder Approximation .	184
6.2.1.	Bound State and Quasiparticle Contributions	184
6.2.2.	The Mass Action Law	188
6.3.	One-Component Plasmas	190
6.3.1.	Analytical Formulae for the Limiting Situations	190
6.3.2.	Padé Interpolations between the Degenerate and the Nondegenerate Cases	193
6.3.3.	Padé Approximations Including Higher Order Interaction Terms and Wigner Crystallization	199
6.4.	Electron-Hole Plasmas	203
6.4.1.	Analytical Results for the Plasma Model	203
6.4.2.	Padé Approximations	206

6.4.3.	Ionization Equilibrium	208
6.5.	Hydrogen Plasmas	210
6.5.1.	The Two-Fluid Model	210
6.5.2.	Basic Formulae for the Limiting Situations and Padé Approximations	212
6.5.3.	Ionization Equilibrium and Phase Diagram	216
6.6.	Alkali Plasmas and Noble Gas Plasmas	221
6.6.1.	Pseudopotentials	221
6.6.2.	The Chemical Potential of the Neutral Component	222
6.6.3.	The Chemical Potential of the Charged Component	224
6.6.4.	Saha Equation and Ionization Equilibrium	225
7.	Transport Properties	232
7.1.	Linear Response Theory	232
7.1.1.	Many-Body Effects and Transport Properties in Non-Ideal Plasmas	232
7.1.2.	Transport Coefficients and Correlation Functions	235
7.1.3.	Further Approaches	239
7.2.	Evaluation of Collision Integrals Using Green's Functions	240
7.2.1.	Green's Functions, Diagrams and Correlation Functions	240
7.2.2.	Evaluation of Correlation Functions in First Born Approximation	242
7.2.3.	Results for a Hydrogen Plasma	244
7.2.4.	Inclusion of the Ionic Structure Factor	249
7.2.5.	Dynamically Screened Second Born Approximation	251
7.2.6.	Statically Screened T-Matrix Approximation. Results	254
7.3.	Further Improvements of the Transport Theory	258
7.3.1.	Self-Energy and Debye-Onsager Relaxation Effects	258
7.3.2.	Hopping Conductivity	259
7.3.3.	Concluding Remarks	261
8.	Green's Function Approach to Optical Properties	264
8.1.	General Formalism	264
8.1.1.	Many-Body Theory of Absorption Spectra	264
8.1.2.	Dielectric Function and Spectral Line Shape of Plasmas	265
8.1.3.	Doppler Broadening	268
8.2.	Evaluation of Line Shift and Broadening	268
8.2.1.	Explicit Expressions for Shift and Broadening	268
8.2.2.	Relation to the Impact Approximation	272
8.2.3.	Shift of Spectral Lines in Dense Hydrogen Plasmas	276
8.2.4.	Estimation of the Shift and Broadening of Spectral Lines for an Argon Plasma	279
8.3.	Further Approaches and Concluding Remarks	281
9.	References	282
10.	Subject Index	296