

CONTENTS

PREFACE	vii
PART ONE □ INTRODUCTION	1
CHAPTER 1 SECOND QUANTIZATION	3
1 THE SCHRÖDINGER EQUATION IN FIRST AND SECOND QUANTIZATION	4
Bosons	7
Many-particle Hilbert space and creation and destruction operators	12
Fermions	15
2 FIELDS	19
3 EXAMPLE: DEGENERATE ELECTRON GAS	21
CHAPTER 2 STATISTICAL MECHANICS	33
4 REVIEW OF THERMODYNAMICS AND STATISTICAL MECHANICS	34
5 IDEAL GAS	36
Bosons	38
Fermions	45

PART TWO □ GROUND-STATE (ZERO-TEMPERATURE) FORMALISM

51

CHAPTER 3 GREEN'S FUNCTIONS AND FIELD THEORY (FERMIONS)

53

- 6 PICTURES 53
 - Schrödinger picture 53
 - Interaction picture 54
 - Heisenberg picture 58
 - Adiabatic "switching on" 59
 - Gell-Mann and Low theorem on the ground state in quantum field theory 61
- 7 GREEN'S FUNCTIONS 64
 - Definition 64
 - Relation to observables 66
 - Example: free fermions 70
 - The Lehmann representation 72
 - Physical interpretation of the Green's function 79
- 8 WICK'S THEOREM 83
- 9 DIAGRAMMATIC ANALYSIS OF PERTURBATION THEORY 92
 - Feynman diagrams in coordinate space 92
 - Feynman diagrams in momentum space 100
 - Dyson's equations 105
 - Goldstone's theorem 111

CHAPTER 4 FERMI SYSTEMS

120

- 10 HARTREE-FOCK APPROXIMATION 121
- 11 IMPERFECT FERMI GAS 128
 - Scattering from a hard sphere 128
 - Scattering theory in momentum space 130
 - Ladder diagrams and the Bethe-Salpeter equation 131
 - Galitskii's integral equations 139
 - The proper self-energy 142
 - Physical quantities 146
 - Justification of terms retained 149
- 12 DEGENERATE ELECTRON GAS 151
 - Ground-state energy and the dielectric constant 151
 - Ring diagrams 154
 - Evaluation of Π^0 158
 - Correlation energy 163
 - Effective interaction 166

CHAPTER 5 LINEAR RESPONSE AND COLLECTIVE MODES

171

- 13 GENERAL THEORY OF LINEAR RESPONSE TO AN EXTERNAL PERTURBATION 172
- 14 SCREENING IN AN ELECTRON GAS 175
- 15 PLASMA OSCILLATIONS IN AN ELECTRON GAS 180
- 16 ZERO SOUND IN AN IMPERFECT FERMI GAS 183
- 17 INELASTIC ELECTRON SCATTERING 188

CHAPTER 6 BOSE SYSTEMS

198

- 18 FORMULATION OF THE PROBLEM 199
- 19 GREEN'S FUNCTIONS 203

20	PERTURBATION THEORY AND FEYNMAN RULES	207
	Interaction picture	207
	Feynman rules in coordinate space	208
	Feynman rules in momentum space	209
	Dyson's equations	211
	Lehmann representation	214
21	WEAKLY INTERACTING BOSE GAS	215
22	DILUTE BOSE GAS WITH REPULSIVE CORES	218

PART THREE □ FINITE-TEMPERATURE FORMALISM 225

CHAPTER 7 FIELD THEORY AT FINITE TEMPERATURE 227

23	TEMPERATURE GREEN'S FUNCTIONS	227
	Definition	228
	Relation to observables	229
	Example : noninteracting system	232
24	PERTURBATION THEORY AND WICK'S THEOREM FOR FINITE TEMPERATURES	234
	Interaction picture	234
	Periodicity of \mathcal{G}	236
	Proof of Wick's theorem	237
25	DIAGRAMMATIC ANALYSIS	241
	Feynman rules in coordinate space	242
	Feynman rules in momentum space	244
	Evaluation of frequency sums	248
26	DYSON'S EQUATIONS	250

CHAPTER 8 PHYSICAL SYSTEMS AT FINITE TEMPERATURE 255

27	HARTREE-FOCK APPROXIMATION	255
28	IMPERFECT BOSE GAS NEAR T_c	259
29	SPECIFIC HEAT OF AN IMPERFECT FERMI GAS AT LOW TEMPERATURE	261
	Low-temperature expansion of \mathcal{G}	262
	Hartree-Fock approximation	262
	Evaluation of the entropy	265
30	ELECTRON GAS	267
	Approximate proper self-energy	268
	Summation of ring diagrams	271
	Approximate thermodynamic potential	273
	Classical limit	275
	Zero-temperature limit	281

CHAPTER 9 REAL-TIME GREEN'S FUNCTIONS AND LINEAR RESPONSE 291

31	GENERALIZED LEHMANN REPRESENTATION	292
	Definition of \bar{G}	292
	Retarded and advanced functions	294
	Temperature Green's functions and analytic continuation	297
32	LINEAR RESPONSE AT FINITE TEMPERATURE	298
	General theory	298
	Density correlation function	300
33	SCREENING IN AN ELECTRON GAS	303
34	PLASMA OSCILLATIONS IN AN ELECTRON GAS	307

PART FOUR □ CANONICAL TRANSFORMATIONS	311
CHAPTER 10 CANONICAL TRANSFORMATIONS	313
35 INTERACTING BOSE GAS	314
36 COOPER PAIRS	320
37 INTERACTING FERMI GAS	326
PART FIVE □ APPLICATIONS TO PHYSICAL SYSTEMS	339
CHAPTER 11 NUCLEAR MATTER	341
38 NUCLEAR FORCES: A REVIEW	341
39 NUCLEAR MATTER	348
Nuclear radii and charge distributions	348
The semiempirical mass formula	349
40 INDEPENDENT-PARTICLE (FERMI-GAS) MODEL	352
41 INDEPENDENT-PAIR APPROXIMATION (BRUECKNER'S THEORY)	357
Self-consistent Bethe-Goldstone equation	358
Solution for a nonsingular square-well potential	360
Solution for a pure hard-core potential	363
Properties of nuclear matter with a "realistic" potential	366
42 RELATION TO GREEN'S FUNCTIONS AND BETHE-SALPETER EQUATION	377
43 THE ENERGY GAP IN NUCLEAR MATTER	383
CHAPTER 12 PHONONS AND ELECTRONS	389
44 THE NONINTERACTING PHONON SYSTEM	390
Lagrangian and hamiltonian	391
Debye theory of the specific heat	393
45 THE ELECTRON-PHONON INTERACTION	396
46 THE COUPLED-FIELD THEORY	399
Feynman rules for $T = 0$	399
The equivalent electron-electron interaction	401
Vertex parts and Dyson's equations	402
47 MIGDAL'S THEOREM	406
CHAPTER 13 SUPERCONDUCTIVITY	413
48 FUNDAMENTAL PROPERTIES OF SUPERCONDUCTORS	414
Basic experimental facts	414
Thermodynamic relations	417
49 LONDON-PIPPARD PHENOMENOLOGICAL THEORY	420
Derivation of London equations	420
Solution for halfspace and slab	421
Conservation and quantization of fluxoid	423
Pippard's generalized equation	425
50 GINZBURG-LANDAU PHENOMENOLOGICAL THEORY	430
Expansion of the free energy	430
Solution in simple cases	432
Flux quantization	435
Surface energy	436

51	MICROSCOPIC (BCS) THEORY	439
	General formulation	439
	Solution for uniform medium	444
	Determination of the gap function $\Delta(T)$	447
	Thermodynamic functions	449
52	LINEAR RESPONSE TO A WEAK MAGNETIC FIELD	454
	Derivation of the general kernel	455
	Meissner effect	459
	Penetration depth in Pippard (nonlocal) limit	461
	Nonlocal integral relation	463
53	MICROSCOPIC DERIVATION OF GINZBURG-LANDAU EQUATIONS	466

CHAPTER 14 SUPERFLUID HELIUM**479**

54	FUNDAMENTAL PROPERTIES OF He II	481
	Basic experimental facts	481
	Landau's quasiparticle model	484
55	WEAKLY INTERACTING BOSE GAS	488
	General formulation	489
	Uniform condensate	492
	Nonuniform condensate	495

CHAPTER 15 APPLICATIONS TO FINITE SYSTEMS: THE ATOMIC NUCLEUS**503**

56	GENERAL CANONICAL TRANSFORMATION TO PARTICLES AND HOLES	504
57	THE SINGLE-PARTICLE SHELL MODEL	508
	Approximate Hartree-Fock wave functions and level orderings in a central potential	508
	Spin-orbit splitting	511
	Single-particle matrix elements	512
58	MANY PARTICLES IN A SHELL	515
	Two valence particles: general interaction and $\delta(x)$ force	515
	Several particles: normal coupling	519
	The pairing-force problem	523
	The boson approximation	526
	The Bogoliubov transformation	527
59	EXCITED STATES: LINEARIZATION OF THE EQUATIONS OF MOTION	538
	Tamm-Dancoff approximation (TDA)	538
	Random-phase approximation (RPA)	540
	Reduction of the basis	543
	Solution for the [15]-dimensional supermultiplet with a $\delta(x)$ force	547
	An application to nuclei: O^{16}	555
60	EXCITED STATES: GREEN'S FUNCTION METHODS	558
	The polarization propagator	558
	Random-phase approximation	564
	Tamm-Dancoff approximation	565
	Construction of $\Pi(\omega)$ in the RPA	566
61	REALISTIC NUCLEAR FORCES	567
	Two nucleons outside closed shells: the independent-pair approximation	567
	Bethe-Goldstone equation	568
	Harmonic-oscillator approximation	570
	Pauli principle correction	574
	Extensions and calculations of other quantities	574

APPENDIXES

579

A	DEFINITE INTEGRALS	579
B	REVIEW OF THE THEORY OF ANGULAR MOMENTUM	581
	Basic commutation relations	581
	Coupling of two angular momenta : Clebsch-Gordan coefficients	582
	Coupling of three angular momenta : the 6- j coefficients	585
	Irreducible tensor operators and the Wigner-Eckart theorem	586
	Tensor operators in coupled schemes	587

INDEX

589