Phys 3707 Many Body Physics/ Intermediate Quantum Mechanics/ Quantum Mechanics III

* Contents

Introduction

many particle systems, single particle states, Fermi sea, Hartree mean field method

Second Quantization

occupation number formalism, one body and two body operators, fermions and bosons, canonical transformations, particle-hole formalism, field operators

Perturbation Theory and Green's Functions

Brillouin-Wigner and Rayleigh-Schroedinger perturbation theory, Goldstone theorem, adiabatic switching, time evolution, scattering theory, Wick's theorem, Green's functions, propagators, spectral function, Dyson equations, Lehmann representation, dispersion relations

Fermi Fluids

Coulomb screening, Gell-Mann -- Brueckner theory, ring diagrams, collective modes and plasmons, effective mass and renormalization, particle lifetimes, random phase approximation, zero sound, Galitskii equation

Light and Matter

review of E&M, gauge invariance, Coulomb gauge, photons, spontaneous emission, black body radiation, Kramers-Heisenberg formula, Thomson, Compton, Rayleigh scattering, photo-electric effect

Spin Systems

spin, para- and ferromagnetism, Heisenberg model, Ising model, spin waves, momentum space, Hubbard model, t-j model, critical phenomena, renormalization group, universality, Lanczos algorithm and numerical methods, spin wave theory, mean field theory

Bosonic Systems

phonons, liquid 4He, density fluctuations, Bogoliubov model, rotons, zero sound

Superconductivity

BCS theory, Eliashberg theory, phonons, Cooper pairs, gap equations

* Course Features

I think that the diagrammatic method and summing diagrams to obtain nonperturbative results in a meaningful way are the central elements of the course. Other many-body methods such as spin wave theory and mean field theory are also important. I have never had time to teach the finite temperature formalism - this time has been used for applications not mentioned in Fetter and Walecka (the course text) such as spin systems, light and matter, coarse graining, and the renormalization group; or for superconductivity (two chapters in F&W).

I polled the students about their interests both times I taught the course. I have found this important because F&W tends to be dry and theoretical, and the students chafe for applications after a month of it.

* Objectives

Students shall be able to apply the diagrammatic methods of nonrelativistic quantum field theory to many body problems, specifically, they will be able evaluate tree and one-loop diagrams.

Students will be able to identify situations in which summing diagrams is important and be able to apply the RPA, ladder, Hartree-Fock, or Galitskii methods to obtain these sums.

Students will be able to apply perturbation theory to obtain bulk properties of simple fermionic systems.

Students will be able to identify and employ the analytic structure of various two-point functions.

Students will be able to compute the masses and life times of quasiparticles in simple many body systems.

Students will able to obtain quantitative estimates of bulk properties and quasiparticle excitations of a variety of spin systems.

Students will be able to apply space renormalization group ideas to simple systems to obtain estimates of critical exponents.

Students will be able to evaluate diagrams describing the interaction of photons with matter; they will understand the principles underpinning the Kramers-Bethe resolution to renormalization in the Lamb shift.

* Prerequisites

Graduate level quantum mechanics is necessary. Exposure to scattering theory and Greens functions methods is very useful; however, in my experience this has not been taught or it has been forgotten.