Ph223ab "Advanced Condensed Matter Physics" (2006 -- 2007)

INSTRUCTOR: Professor Nai-Chang Yeh
(Office: 128-36 Phone: x-4313 E-mail: ncyeh@caltech.edu)

SCHEDULE: Monday & Wednesday 10:30 – 12:00

LOCATION: Downs 103

INFORMATION: http://www.its.caltech.edu/~yehgroup/ph223_2006

GTA: Yue Zou
(Mail Code: 114-36 Phone: x-3422 E-mail: zou@caltech.edu)

Ph223ab

I. Introduction

-- Overview of modern condensed matter physics.
-- Review of the Schrödinger, Heisenberg and interaction pictures.

II. Quantum Field Theory for Many-Body Systems

-- Review of the canonical and path-integral formalisms; Feynman diagrams.
-- From relativistic to non-relativistic quantum field theory.
-- Green's function techniques for many-body systems.
-- Hartree-Fock and random phase approximations.
-- Linear response and correlation functions, Kubo formula.
-- Fluctuation-dissipation theorem.

III. Fermi Liquid Theory

-- Overview of the Fermi liquid theory – phenomenology.
-- Vertex contributions to the Fermi liquid theory – the quantum-field approach.
-- Basic physical relations of the Fermi liquid theory and bosonic excitations.
-- Electron-phonon interactions.
-- Limitations of the Fermi liquid theory & Luttinger liquid theory.

IV. Interacting Bosons and Superfluidity

-- Basic formalism for interacting bosons at $T = 0$.
-- Perturbation theory and Feynman rules.
-- Weakly interacting bosons.
-- Field theory of interacting bosons at $T \neq 0$.

-- Bosonic superfluid in liquid helium.

V. <u>Theory of Conventional Superconductivity</u>

-- Basic phenomena of superconductivity.
-- The Cooper instability and electron pairing.
-- Microscopic theory of superconductivity.
-- Thermodynamic properties of superconductors.
-- Theory of quasiparticle and Cooper pair tunneling.

VI. <u>Gauge Theory</u>

-- Gauge invariance.
-- Topological objects: solitons, vortices, monopoles, and instantons.
-- Spontaneous symmetry breaking and the Nambu-Goldstone bosons.
-- Non-abelian gauge theory.*
-- Anderson-Higgs mechanism.*
-- Duality.*

VII. <u>Unconventional Superconductivity</u>

-- Unconventional pairing symmetries in novel superconductors.
-- Phenomenology of high-temperature superconductivity: doped Mott insulators, competing orders, quantum fluctuations, unconventional low-energy excitations, and pseudogap phenomena.
-- Microscopic theories: the *t-J* and Hubbard models; RVB and spin-liquid states; the $U(1)$, $SU(2)$ and Z_2 slave-boson gauge theories.
-- Heavy-fermion superconductivity.*

(*Topics to be covered contingent upon available time.)

<u>Text Books</u>:

1. "*Quantum Theory of Many-Particle Systems*", A. L. Fetter and J. D. Walecka, Dover Publications, Inc. (2003).

<u>Reference Books</u>:

1. "*Methods of Quantum Field Theory in Statistical Physics*", A. A. Abrikosov, L. P. Gorkov, and I. E. Dzyaloshinski, Dover Publications, Inc. (1975).

2. "*Quantum Field Theory in a Nutshell*", A. Zee, Princeton University Press (2003).

3. "*Quantum Field Theory*", L. H. Ryder, Cambridge University Press, 2nd Edition (1996).

4. "*Quantum Field Theory of Many-Body Systems*", X.-G. Wen, Oxford University Press (2004).

5. "*Theory of Superconductivity*", J. R. Schrieffer, Westview Press (1999).

6. "*Introduction to Superconductivity*", M. Tinkham, Dover Publications, Inc.