

# Syllabus

Physics 625 (Spring, 2010) — **Non-relativistic Quantum Mechanics**

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Course web-site: <http://www.wam.umd.edu/~galitski/PHYS625/>

Office hours: Monday, Wednesday; 2:00 p.m. – 3:00 p.m., room PHYS 2330

Lectures: Monday, Wednesday; 12:30 p.m. – 1:45 p.m., room PHYS 4220

## Summary

The purpose of this course is to provide a graduate-level introduction to quantum many-body physics and condensed matter physics. This will include an introduction to second quantization, Green's function formalism, Feynman diagrammatic technique, Kubo linear response theory, Fermi liquid theory, Bardeen-Cooper-Schrieffer theory of superconductivity, theory of phonons in solids, theory of disordered quantum systems (in particular, localization), and (time permitting) path integral formalism.

## Reading

- *Main text:* G. D. Mahan, “Many-Particle Physics,” Plenum (1990)
- *Not required, but HIGHLY recommended text:* Al. Altland and B. Simons, “Condensed Matter Field Theory,” Cambridge University Press (2006)
- A. A. Abrikosov, L. P. Gor'kov, and I. E. Dzyaloshinskii, “Quantum Field Theoretical Methods in Statistical Physics,” Oxford (1965)
- N. W. Ashcroft and N. D. Mermin, “Solid State Physics,” Saunders College Publishing (1976)

**Homework:** There will be, on average, one homework assignment every two weeks.

**Exam:** There will be (possibly) a mid-term exam and a take-home final exam.

## Grading

Homework: 50%

Exam(s): 50%

## Outline

1. Elements of single particle-quantum mechanics (warm-up/reminder)
  - (a) Green's function of the Schrödinger equation
  - (b) Simplest example of the diagrammatic technique: a pictorial representation of the scattering amplitude in single-particle quantum mechanics
2. Feynman path-integral in single-particle quantum mechanics
  - (a) Path integral for spin
  - (b) Topological Berry's phases and Wess-Zumino terms
3. Many-particle Quantum Mechanics: Non-interacting classical and quantum gases; Boltzmann, Fermi, and Bose distributions
  - (a) Properties of a Fermi gas
  - (b) Properties of a Bose gas; Bose condensation
4. Second quantization; Bogoliubov transformation
  - (a) Classical chain of oscillators; Acoustic and optical phonons
  - (b) Quantum chain of oscillators
  - (c) Quantum fermionic chain
  - (d) One-dimensional quantum spin systems; Non-local Jordan-Wigner transformation. New emergent degrees of freedom in many-particle systems
5. Methods of quantum field theory in condensed matter physics;
  - (a) Schrödinger, Heisenberg, and interaction representations;  $S$ -matrix
  - (b) Green functions in many-particle systems; Perturbation theory and Feynman's diagrammatic technique for interacting particles
  - (c) Physical meaning of Green functions; Spectrum of quasiparticles
  - (d) Two-particle Green's function; Self-energy function
6. Application of the Green's function formalism to electronic systems
  - (a) Friedel oscillations and the Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction between magnetic impurities in metals
  - (b) Electron-phonon interaction; Polaron in the weak-coupling approximation; Self-energy and effective mass
  - (c) Anderson orthogonality catastrophe
  - (d) Peierls transition
7. Fermi liquid theory and elements of superconductivity
  - (a) Landau Fermi liquid theory; Phenomenology and microscopic justification

- (b) Collective modes: Zero sound and plasmons in an electron gas
  - (c) Instabilities in a Fermi liquid
  - (d) Superconducting instability and Cooper pairs
  - (e) BCS wave-function
8. Generalized susceptibility; Kubo's formula for linear response quantities