Spring 2013 **Syllabus**

Physics 622: Quantum Mechanics II

TTh 11:00-12:20 in Small Hall room 233

Prerequisite: PHYS 621

Instructors

Prof. Seth Aubin
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Office hours: Aubin: Wednesday, 3-4 pm; Gani: Monday, 3-4pm;
Rodriguez-Vega: Tuesday 2-3pm.

Course Objectives

The primary purpose of this course is to cover quantum mechanics and related calculation methods as applied to atomic, molecular, optical, solid state, particle, and many-body systems.

The course will cover the following topics:

- Hydrogen-like atoms, fine and hyperfine structure
- Stark effect and Zeeman effect
- Time-independent perturbation theory
- Variational method
- Time-dependent perturbation theory
- 2-level systems, 3-level systems, Rabi flopping
- Symmetries: Parity, time-reversal, lattice translation
- Identical particles
- Multi-electron atoms
- Scattering theory: from particle physics to cold atoms
- Second quantization: Bose-Einstein condensates
- Quantization of the electromagnetic field
- Relativistic quantum mechanics, Dirac equation

Course Materials

Text: Most of the course materials and problem sets will be taken from the following required text for the course:

Modern Quantum Mechanics, by J. J. Sakurai and J. Napolitano (2nd ed., 2011).

Some course materials will also be taken from the following texts:

Quantum Mechanics, by L. D. Landau and E. M. Lifshitz (3rd ed., 2003).

Quantum Mechanics, by C. Cohen-Tannoudji, B. Diu, and F. Laloë (1st ed., 1992).

Quantum Mechanics, by L. I. Schiff (3rd ed, 1968).

Evaluations

Your final grade for the course will be determined from the following grading weight distribution:

Problem sets:	45%
Participation:	10%
Midterm:	15%
Final Exam:	30%

Problem sets: The problem sets are the main evaluation of learning for the course and also serve as a significant means of learning the material. Students are expected to do the problems on their own (not as a team effort with other students), though discussion and limited oral consultation with other students is encouraged.

Participation: The classroom presentation of course material will involve class discussions. All students are expected to participate in these discussions, since they will help elucidate the course material. Participation also reflects class attendance and the occasional quiz.

Midterm: The midterm will cover course material from the first half of the course.

Final exam: The final exam will cover all the material in the course, but with an emphasis on the second half of the course.

Weekly Schedule (tentative)

Week 0: 1/17 **Hydrogen Atom Review**
Hamiltonian, energy levels, electronic states.

Week 1: 1/22-24 **Perturbation Theory (time-independent)**
Basic theory, degenerate theory, effect of nuclear radius, Van der Waals interactions.

Week 2: 1/29-31 **Variational Method**
Computing modification to ground state energies, no-level-crossing theorem

Week 3: 2/5-7 **Stark and Zeeman Effects**
Interaction of an atom with electric and magnetic fields.

Week 4: 2/12-14 **Fine and Hyperfine Structure**
Spin-orbit coupling, nuclear spin

Week 5: 2/19-21 **2-Level Systems**
Rabi oscillations, rapid adiabatic passage, Landau-Zener transitions.

Week 6: 2/26-28 **Perturbation Theory (time-dependent)**
Fermi's golden rule, sinusoidal perturbations, transition amplitudes.

------------------------------ Spring Break ------------------------------

Week 7: 3/12-14 **Midterm**

Week 8: 3/19-21 **Fundamental Symmeries**
Parity (and parity violation), time-reversal, lattice translation.

Week 9: 3/26-28 **Identical Particles**
Bosons, Fermions, Pauli exclusion principle, helium, multi-electron atoms.

Week 10: 4/2-4 **Scattering Theory**
T matrix, Lippman-Schwinger equation, Born approx., partial wave expansion.

Week 11: 4/9-11 **Scattering … Second Quantization**
Scattering length, many-body physics, Gross-Pitaevskii equation.

Week 12: 4/16-18 **Quantization of the Electromagnetic Field**
Hamiltonian approach, photons, Casimir force.

Week 13: 4/23-25 **Dirac Equation**
Klein-Gordon equation, gamma matrices, anti-particles, hydrogen revisited

May 6, 2013, 14:00-17:00 **Final Exam**