Course: Physics 571
Term: Fall, 2019
Room: TBD
Class: MWF, 9:00-9:50 am

Instructor Contact Information

Instructor: Randall Hulet
Office: BRK 391
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Office Hours: By appointment

Course Objectives and Learning Outcomes

Research activity in *Atomic, Molecular and Optical science* (AMO) has grown rapidly over the past 30 years, particularly in the field of *ultracold atomic physics*. This growth has arisen from the development of novel techniques for cooling atoms which has moved the low temperature frontier into the nano-Kelvin regime. Access to ultracold temperatures has enabled applications such as ultra-precision spectroscopy, new types of atomic clocks, and atomic gyroscopes. At sufficiently low temperatures, a gas of atoms becomes quantum degenerate where bosonic atoms undergo a transition to a *Bose-Einstein condensate* (BEC), and where fermionic atoms may pair to become a superfluid. This research has provided new insight into the quantum world and provides a new domain for exploring many-body physics.

The aim of Physics 571 is to provide the student the foundation of quantum mechanics and atomic physics needed to participate in this exciting new field. We will start with some traditional atomic physics of hydrogen and hydrogen-like atoms, followed by the study of atom-photon interactions. With this background, we will discuss various cooling and trapping techniques for neutral atoms, and the physics of quantum degenerate gases.

Recommended Texts

You are not required to purchase each of these books, but access to them is helpful.

"Atoms and Molecules Interacting with Light", by P. van der Straten and H. Metcalf
"Atomic Physics", by C. J. Foot
"Advances in Atomic Physics: An Overview", by C. Cohen-Tannoudji and D. Guéry-Odelin

Exams and Papers

There will be an oral final exam.

Grade Policies

Grades will be based on problem sets (40%), class presentation on current research topics (30%), and a final exam (30%)

Working together on problem sets is encouraged, but consulting prior year's homework or solutions is a violation of the honor code.

Rice Honor Code

In this course, all students will be held to the standards of the Rice Honor Code, a code that you pledged to honor when you matriculated at this institution. If you are unfamiliar with the details of this code and how it is administered, you should consult the Honor System Handbook at http://honor.rice.edu/honor-system-handbook/. This handbook outlines the University's expectations for the integrity of your academic work, the procedures for resolving alleged violations of those expectations, and the rights and responsibilities of students and faculty members throughout the process.

Disability Support Services

If you have a documented disability or other condition that may affect academic performance you should: 1) make sure this documentation is on file with Disability Support Services (Allen Center, Room 111 / adarice@rice.edu / x5841) to determine the accommodations you need; and 2) talk with me to discuss your accommodation needs.

Course Outline

I. Atomic Physics

A. Hydrogen and hydrogen-like atoms

1. Non-relativistic theory (review); atomic units
2. Fine and hyperfine structure
3. Effect of static magnetic fields
4. Rydberg atoms
5. Lamb shift and spontaneous decay

B. Atom/photon interactions

1. Density matrix and optical Bloch equations
2. Dressed states
3. 3-level systems: Autler-Townes effect, dark states
4. Laser spectroscopy
5. Ramsey method: Block sphere

C. Cooling and trapping of neutral atoms

1. Light pressure forces
2. Atom cooling: Doppler, evaporative
3. Atom trapping: magneto-optical, magnetic, optical
4. Optical lattices

II. Quantum Degenerate Gases

A. Bose-Einstein condensation

1. BEC in an ideal gas
2. Atomic collisions and the scattering length; Feshbach resonances
3. Weakly-interacting atomic condensate

B. Quantum degenerate fermions

1. Equilibrium properties
2. BEC-BCS crossover