Atomic and Optical Physics I
Physics 721
Tuesdays and Thursdays
10:30 – 11:45
Physics Rm. 3301

Instructors: William D. Phillips (University of Maryland and National Institute of Standards and Technology) and James V. Porto (National Institute of Standards and Technology) will team-teach this class:
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There is no formal textbook for this course. At the end of this page you will find suggested helpful references.

Office hours by arrangement, in Physics Rm. 2123
(for example, before or after class or other times that are mutually convenient)

The grade for this class will be based on homework, a take-home exam, and a written presentation.

Syllabus: Topics and the approximate order of treatment

- Review of classical electromagnetic waves and the atom-light interaction Hamiltonian.
- Quantization of the electromagnetic field—the photon.
- Einstein's theory of radiation: the A and B coefficients. Cross section for scattering of light by atoms.
- Resonant interaction of light with a classical harmonic oscillator: line shapes for absorption and dispersion.
- Two-level atom, quantized field description of absorption, spontaneous and stimulated emission.
- Two-level atom interacting with a monochromatic field: Rabi oscillations, the density matrix and optical Bloch equation.
- Atomic structure: energy levels of one- and two-electron atoms (e.g., He and alkalis). Spin-orbit coupling, fine and hyperfine structure, the role of symmetry, Rydberg states.
- Angular momentum in atomic physics: review of the Wigner-Eckhart theorem; using Clebsch-Gordan coefficients (3-j symbols) and 6-j symbols to calculate matrix elements.
- Dressed atoms: The unified system of atoms+photons+atom-photon interactions.
- Atomic spectroscopy: experimental techniques of linear and non-linear spectroscopy.
- Atom-laser interactions I: The light shift, perturbative and non-perturbative treatments; scalar and tensor light shifts.
- Atom-laser interactions II: resonance fluorescence, dipole radiation patterns, the Mollow triplet, the Lamb-Dicke effect.
- Optical pumping.
- Zeeman and Stark effects: The Breit-Rabi formula, the Hanle effect, quadratic and linear Stark effects; Stark-induced transitions; atomic (and molecular) dipole moments.
- Three-level atoms: coherent population trapping; electromagnetically induced transparency.

- Classical theory of the coherence of light: correlation functions and the power spectrum of light; the Hanbury Brown-Twiss effect.
- Quantum optics: non-classical states of light
- Laser Cooling and Trapping
- Bose-Einstein condensation.

Suggested helpful references:

Optical Resonance and Two Level Atoms, by L. Allen, J. H. Eberly (1987)

The Quantum Theory of Light (Oxford Science Publications), by Rodney Loudon; (2000)

Atomic Physics: An Exploration Through Problems and Solutions by Dmitry Budker, Derek Kimball and David DeMille (2004).

Atom-Photon Interactions : Basic Processes and Applications, by Claude Cohen-Tannoudji, Jacques Dupont-Roc, and Gilbert Grynberg (1998).

Additional reference works may be suggested as the course progresses.