Ph 137a – Atoms and Photons
Fall 2020 Preliminary Course Information

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Content The main goal is to give students the background necessary to understand and contribute to modern experiments that use coherent quantum techniques. We focus on atoms, though the concepts that we cover are transferrable to many systems.

Prerequisites Graduate-level quantum mechanics, e.g. Ph 125abc, or instructor's permission.

Lectures Lectures will not follow a single textbook, but suggested readings will be given throughout the course. Typed lecture notes will be made available. *Attendance at the lectures is highly recommended since discussions are an important part of them.*

Grade 80% problem sets, 20% presentation. We will drop the lowest 12.5% of your problem set scores in computing your final grade, but problem sets will still contribute at most 80% of your final grade, according to the following formula:

$$Final\ \% = 80\% \times Min\left[\frac{Earned\ prob.set\ points}{87.5\% \times (Possible\ prob.\ set\ points)}, 100\%\right] + 20\% \times \frac{Earned\ presentation\ points}{Possible\ presentation\ points}$$

Minimum grade percentage cutoffs are below. Curves will only be used to increase grades. A grade of D or higher is required to pass the class.

A+	A	A-	B+	B	B-	C+	C	C-	D+	D	F
95	90	87	84	80	77	74	70	67	64	60	<60

Problem sets Eight sets, each with equal weight for grades. Collaboration is strongly encouraged.

Collaboration *Short version*: Open everything, except previous solution sets. All work must be your own, and you must indicate what/whom you consulted. *Longer version*: You are free to consult any textbooks, online resources, people, *etc*. Everything submitted must be your own work that you understand and show (including code), and you must indicate any resources used. You may not consult solutions sets for this course from earlier years or previous versions (Ph 103).

Extensions Extensions granted only for health, family, emergency, or religious reasons. Lots of other homework, preparing for ditch day, *etc*. do not count, but you should always contact us or the deans if you are having trouble. In lieu of extensions, we will drop 12.5% of the homework (equivalent to a full set) as described above.

Presentation Students will research a topic of their choosing and present their findings to the class, in the spirit of a journal club. Details to be decided later in the course.

Honor Code *"No member of the Caltech community shall take unfair advantage of any other member of the Caltech community"* applies to all aspects of this course.

Inclusion and Accessibility Everyone is welcome in this class and at Caltech, and everyone is responsible for creating a welcoming environment. Please contact us with any concerns, or if any accommodations are needed. You can also contact the Caltech Accessibility Services for Students (CASS), or the deans.

Learning Outcomes

After taking this course, students will be able to:

- Describe the features of coherent quantum systems and their interactions with external perturbations, especially electromagnetic fields.
- Understand atomic structures, along with their physical origins and their effects on properties, spectra, and interactions.
- Relate the response of atoms in static fields to their response in alternating fields, such as lasers and microwaves, and understand how they can be probed and controlled through those means.
- Apply these concepts to understand contemporary research techniques such as laser cooling and trapping, and the science goals that they enable.

Approximate course outline

Feel free to suggest additional topics that you would like to see on the list.

Two-level systems and resonance. Classical and quantum magnetic resonance, rotating frames.

Atomic structure. Hydrogenic atoms, electronic structure, fine and hyperfine structure, multi-electron atoms.

Atoms in static fields. Zeeman and Stark effects, angular momentum coupling.

Atoms in alternating fields. Einstein A and B coefficients, dipole approximation, Optical Bloch Equations, saturation, cross-sections, broadening, M1/E2 transitions.

Cooling and trapping. Laser cooling, laser slowing, magneto-optical trapping, dipole trapping, magnetic/electric trapping.

More complex systems. Raman transitions, adiabatic elimination, atomic clocks, STIRAP, EIT/CPT, fundamental symmetry violations and searches for new physics, optical lattices, and synthetic quantum matter.

Suggested books

There are no required books, but here are some to which I will refer often and should be on reserve in the library. *The first two books will be especially useful for the problem sets.*

Foot, *Atomic physics*. Good introductory overview, probably worth buying since it is inexpensive.
Budker *et al.*, *Atomic physics*. Not introductory; amazing conceptual discussions.
Steck, *Quantum and Atom Optics*. Great book, available for free at *http://steck.us*
Fox, *A Student's Guide to Atomic Physics*. Good introductory overview.
Weiner and Ho, *Light-matter interaction*. Good, short, introductory overview.
Metcalf and Van der Straten, *Laser cooling and trapping*. Standard text for atom trappers.
Metcalf and Van der Straten, *Atoms and Molecules Interacting with Light*. New version of above.