

Course Outline: Physics 475: Atomic and Molecular Physics
Carl Adams, Winter Term 2010-11

1. **Summary:** This course provides an introduction to the field of atomic and molecular physics. This will include a description of classic historical experiments and results and theoretical concepts from quantum mechanics. An experimental lab is part of the course.
2. **Text:** *Atomic Physics*, Christopher Foot, Oxford Master Series in Atomic, Optical, and Laser Physics
3. **Other references:** Foot is a good book and is packed with information but it *does not include* a lot of background derivations. You should have enough knowledge from the prerequisite courses (PHYS 343 and its pre-reqs PHYS 201, PHYS 242, and a strongly recommended PHYS 325) to understand what Foot refers to but you will likely need to consult some of your previous notes and textbooks (Tipler and Llewellyn's *Modern Physics*, Hecht's *Optics*, Ballentine's *Quantum Mechanics: A modern development*, Marchildon's or Griffiths' *Quantum Mechanics* or another QM reference such as Messiah's 2 volume *Quantum Mechanics* or Dirac's *The Principles of Quantum Mechanics* (Please don't lose this one; I won it as a prize as an undergrad). The previous text for this course *Physics of Atoms and Molecules*, 2nd edition, B.H. Bransden and C.J. Joachain provides a considerable amount of this information. Look for these in the library or on the shelf outside of my office.
4. **Grading scheme:**
 - Assignments (4) 20%
 - Midterm (2) 20% (take place in class Feb. 16, Mar.23)
 - Lab 20%
 - Comprehensive Final Exam 40%

I draw your attention to Section 3.8 of the Academic Calendar **Academic Integrity Policy** and online at

<http://www.stfx.ca/services/registrar/policies>

Assignments are due at the beginning of class if there is a class on the due date and by 4 p.m. if there is no scheduled class that day. The assignment mark will be penalized by 10% for each teaching day the assignment is late after the due date up to a maximum of one week. After one week or if in special circumstances where I circulate solutions prior to that time (a warning will be given) the assignment will be worth zero. (I may still mark the assignment if you would like to see how well you did.) I will do my best to return the assignments within 10 days or sooner. A considerable portion of the midterm and exam questions will be based on assignments and examples covered in class and in the book so it is very important that you understand these solutions. *All midterms and exams will be closed book with one double sided formula sheet.* There are no scheduled tutorials for this class but if the class wishes I will try to arrange for a question and answer doughnut period prior to the midterm.

5. **Website:** <http://people.stfx.ca/cadams/physics475/>
6. **Office Hours:** Rm 1006 Physical Sciences Complex, x5337 or in research lab PS 1070. Email: cadams@stfx.ca. I am usually in my office or lab from 10 to 5 each day with the exception of Mondays, classes, and labs. Formal office hours will be Tuesday 10:15 to 12:05, Wednesday 11:15 to 12:05, Thursday 10:15 to 12:05, and Friday 11:15 to 12:05. This overlaps with blocks A, B, E, F, M, and P. Let me know if you would like a special appointment.

7. **Course Outline:** Follows chapters 1-7 with topics from other chapters. The topics covered are not identical to those mentioned in the calendar course description (e.g. I don't plan on covering scattering theory) which are largely there for historical reasons that reflected the expertise of the instructors. Items marked with a (*) are not covered in Foot but are part of the course material.

- (a) Early atomic physics
 - i. Basis for atomic theory (*)
 - ii. Bohr model of the hydrogen atom
 - iii. Radiative decay and Einstein coefficients
 - iv. Zeeman effect
- (b) The hydrogen atom
 - i. Energy Levels and Eigenfunctions
 - ii. Transitions
 - iii. Relativistic Corrections and Fine Structure
 - iv. Spectroscopic notation
 - v. Lamb Shift
- (c) Multi-electron atoms
 - i. Ground and excited states of helium
 - ii. Evaluation of direct and exchange integrals
 - iii. Shell structure
 - iv. Fine structure and other properties of alkalis
 - v. LS -coupling scheme
- (d) Hyperfine structure and isotope shift
- (e) Interaction with radiation
- (f) Current AMO Topics (laser, laser cooling, quantum computing, etc.)

Quantum mechanics runs through most of the topics. Here are a few of the topics we will see.

- (a) Schrödinger's equation
- (b) Operators, commutators, eigenvalues
- (c) Angular momentum (orbital and spin)
- (d) Symmetries of the Hamiltonian (parity, particle exchange)
- (e) Central forces and separation of variables
- (f) Time independent, degenerate, and time dep. perturbation theory
- (g) Semi-classical treatment of electromagnetic radiation
- (h) Relativistic corrections
- (i) Variational principle

Yikes! But this *isn't* a quantum mechanics course, similar to the way that PHYS 322 is not a vector calculus course.

8. **Labs:** Some labs will be looking back at something you have done before and some will be looking forward. You will need to test certain things and learn about their operation before proceeding with measurements and analysis. I “plan” labs on the following topics: Millikan oil drop, electron spin-resonance, Rutherford scattering, gas discharge, Zeeman effect, spectrographic analysis, electron spectroscopy, x-ray spectra, electrolysis, magnetic torque, and carbon dioxide lasers. I will determine your lab mark using the following scheme: attendance/interest (15%), record keeping (15%), good experimental practice and skill (25%), data presentation and analysis (25%), and ability to form conclusions (20%). Your lab book will be your written record of what you have done. I expect a bit more written down about procedures than you may have done in the past. Analysis should also be complete. I will give you a midterm mark on this. I will take the lab books in on Jan. 21, Feb. 18, March 18, and on the day of the final exam. The labs will be spread through several of the undergrad labs on the 1st floor of the PSC.