Course Syllabus for PHYS 5620: Atomic Physics

2018 Spring semester

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Website for this course: https://www.ricespectroscopylab.com/atomic-physics

Pre-requisites: PHYS 4310 (or equivalent) and PHYS 5410 (or equivalent)

Lecture location and time: TBD

Exam 1: The mid-term will be on Thursday, March 8th during class.

Office hours: MWF, 9:00—10:30 am or by appointment.

Textbook: *Atomic Physics: An Exploration through Problems and Solutions* by D. Budker, D. Kimball, and D. DeMille

Other Important and Useful (but not required) Texts:

- *Introduction to Quantum Mechanics, 2nd edition* by D. J. Griffiths (2005)
- *Introduction to Elementary Particles, 2nd edition* by D. J. Griffiths (2008)
- *Modern Quantum Mechanics* by J. J. Sakurai (1994)
- *Photon-Atom Interactions* by M. Weissbluth (1989)
- *Bose-Einstein Condensation in Dilute Gases* by C. J. Pethick and H. Smith (2002)
- *Quantum Mechanics (Non-Relativistic Theory), 3rd edition* by L. D. Landau and E. M. Lifshitz (1977)

Course Content

This graduate course introduces major themes, topics, and techniques in modern atom physics. Topics covered will include:

- Atomic structure, Schrödinger equation in atomic units, atomic nomenclature, Rydberg atoms
- Spin-orbit and exchange interactions
- Fine and hyperfine structure, addition of angular momenta, Clebsch-Gordon coefficients
- Model atomic system: Geonium
- Conservation rules, CPT symmetry
- Atoms in external fields
- Interaction of light with atoms
- Interaction of light with atoms in an external field
- Atomic collisions

- Cold Atoms
- Intro to relativistic quantum mechanics and the Dirac equation

General Outline of the Course

As the name implies, this course introduces the topic of atomic physics to graduate students. I anticipate it will be applicable to students in physics (atomic, molecular, and optical physics and condensed matter physics, specifically), astronomy, physical chemistry, and certain branches of engineering. That being said, any student, undergraduate or graduate, who is interested in this material and has the requisite mathematical background is highly encouraged to take this class.

Broadly, we will examine how atoms are categorized, described, and explained, including in the presence of electric and magnetic fields. Interesting and current phenomena, such as atomic collisions, Bose-Einstein condensates, superfluids, and atomic cooling techniques, will be discussed. A short introduction to the Dirac equation (relativistic quantum mechanics) and Fenyman diagrams will also be covered.

More precisely, we will first start by introducing the hydrogen atom, Schrödinger equation with atomic units, structure of the atom, and Rydberg atoms. Continuing with fundamentals, we will move on to spin-orbit and exchange interactions, fine and hyperfine structure, addition of angular momenta, and important atomic models. Next, we will cover how atoms behave in external fields and how they interact with light. Afterwards, we will focus on atomic collisions (broadening mechanisms, Dicke narrowing, spin exchange, and Penning ionization) and cold atoms (Bose-Einstein condensates, cooling techniques, superfluidity, and superconductivity). Last, we will discuss relativistic quantum mechanics and introduce the Dirac equation.

Grading Standards

Course Grade:

Your grade will consist of: Homework (20%), Oral Presentations (30%; 12% for presentation 1 and 18% for presentation 2), Exam 1 (12%), Paper (15%), Class Participation (5%), and Final exam (18%). I will grade on an A, B, C, D, F scale with an A being defined as >89%, a B >79%, a C > 69%, a D >59%, and an F <60%.

Homework, including late policy:

Homework is to be turned in at 18:00 on the due date. It will be accepted up to 12 hours late without penalty; after that, 10% of the full grade will be assessed for each day it is late. If the homework is over five days late, it will not be accepted.

Grading for Class Presentations

You are required to give two oral presentations during the semester. The first presentation will be ten minutes long and will cover a recent *refereed* article that I will assign to you. For this first presentation, you will be allotted ten minutes of speaking time and up to eight slides (use of the white board for up to one-half of your presentation is also allowed). Two weeks before this presentation, you will submit a rough draft of your talk (20% of the presentation grade) for feedback.

I strongly prefer the so-called IMRAD format for both presentations and write-ups: Introduction, Methods, Results, Analysis, and Discussion. For the introduction, it is expected that you frame the question by presenting background (not too much, though) on the problem and what the critical gap in knowledge that the researchers are trying to address. This section is often the hardest to do correctly. For methods, which is often the shortest part of any talk, you should succinctly cover the relevant parts of the experiment/theory being presented. Extraneous details about the method should be scrupulously avoided, since this type of deep dive will undoubtedly overwhelm, confuse, and annoy the listener. Results, as the name implies, is a clear, direct, and logical presentation of the results. Often, as results are presented, the relevant analysis (and sometimes discussion) is also included. This can be helpful whenever distinct or unrelated parts of the paper are being discussed within the same talk. Analysis refers to the methods and techniques used to explain the data. For instance, if you are describing variable range hopping behavior, which has a distinct $\exp(T^{-1/1+d})$ behavior for resistance, you may introduce that dependence and then explain that you plotted your data as $\ln(R)$ vs. $T^{-1/1+d}$ and then fit a line to that data. Last, discussion should focus on what was found and its implications. Was the data explained by the theory? What new physics was found? Did the new theoretical interpretation offer a new insight or an incremental improvement?

Note that this exercise will be excellent preparation for presentations you will make at national meetings (*e.g*, the *American Physical Society* or the *Materials Research Society*). For example, *APS* March Meeting speakers are limited to a whopping ten minutes, with two minutes for questions making concise presentation not an option but a **necessity**. Presenting effective, impactful ideas about important topics in a short amount of time is a tremendous challenge that is relevant to nearly all modern-day careers.

The second presentation will be over three articles (including the first one that you presented earlier in the semester) that are all closely related. Unlike the major article, which was assigned to you for the first presentation, for this three-article presentation, you are required to choose the other two articles. For example, it could be a series of articles disputing some

interpretation of a phenomenon or a collection showing how a technique has been developed and improved. This presentation will be 20 minutes long with up to 20 slides. Additionally, you will write a short (not to exceed five pages, including references) paper on your chosen article collection. The presentations will take place on the last week of the semester with the paper being turned in on finals week.

Presentation rubric:

Graphical presentation and slide layout (out of 15 points)
Explanation of relevant points in the paper (out of 20 points)
Appropriate discussion of background and identification of the important questions/problems (out of 15 points)
Handling of questions (out of 10 points)
Speed and pacing of presentation (out of 10 points)

Academic Honesty

The University of Wyoming is built upon a strong foundation of integrity, respect and trust. All members of the university community have a responsibility to be honest and the right to expect honesty from others. Any form of academic dishonesty is unacceptable to our community and will not be tolerated (from the UW General Bulletin). Teachers and students should report suspected violations of standards of academic honesty to the instructor, department head, or dean. Other University regulations can be found at:
http://www.uwyo.edu/generalcounsel/new-regulatory-structure/index.html
Academic dishonesty is defined in University Regulation 802, Revision 2 as "an *act attempted or performed which misrepresents one's involvement in an academic task in any way, or permits another student to misrepresent the latter's involvement in an academic task by assisting the misrepresentation."* There is a well-defined procedure to judge such cases, and serious penalties may be assessed.

Absences/Attendance/Participation Policy:
University sponsored absences are cleared through the Office of Student Life. If possible, please let me know that you will be absent before any planned or extended-duration excused absences. For excused absences **only**, I will provide make-up times for exams, extend homework due dates, and re-arrange presentation times depending on when the excused absence occurs.

Special accommodations

If you have a disability and require accommodations, please let me know as soon as possible. You must register with, and provide documentation of your disability to University Disability Support Services (UDSS) in SEO, room 330 Knight Hall.

Expectations and Outcomes

Consider reading "A&S Students and Teachers—Working Together" found at www.uwyo.edu/as/_files/current/Students%20and%20Teachers%20Working%20Together.pdf. This useful set of guidelines was written by a faculty and student committee. It is a concise attempt to inform students of instructor expectations as well as what students may expect of teachers and advisors.

My hope is that by the end of this course, you will have a working knowledge of the main topics in atomic physics and the fundamentals of the discipline. Furthermore, I expect that you will have a generalized knowledge of what is the state-of-the-art in terms of research and current intellectual trends in atomic physics. Last, I hope that each of you improve your insight into high-level research (papers, statements, experimental design, theoretical concepts, etc.), professional writing ability, and scientific presentation skills.

What I expect from you (specifics):

- To attend and participate in each class meeting. It is your responsibility to obtain and understand the material presented, even if you are not in attendance due to illness or a University-sponsored activity.

- To make a good effort and to be prompt in completing assignments.

- To spend about ten hours per week on this course. If you are spending more time than this, please see me so that we can ensure you spend your time efficiently.

What you should expect from me:

- To cover the material outlined.

- To administer feedback questionnaires, to better gauge your needs.

- To expeditiously grade and return your work.

- To provide deep insight above and beyond the assigned material.

During the semester, I will communicate to each of you, in writing, any substantive changes made to this syllabus.