COURSE INFORMATION

Course: Atomic Physics (Physics 925)

Fall 2023, TuTh, 12:30 - 13:45 247 JH

Instructor: Prof. Ilya I. Fabrikant, 310P JH, tel. 472-2774
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Office Hours: TuTh 10:00 - 11:00 or by appointment

If in-person classes are canceled due to severe weather, you will be notified of the instructional continuity plan for this class by email.

When circumstances (weather, illness) prevent instructor or students from attending class in-person, the following methods will be used:

Instructor absent: zoom session will be organized

Student absent: notes from the instructor (in addition to those posted on Canvas) will be provided upon request. Also, questions-and-answers zoom session will be available upon request.

UNL Course Policies and Resources: Students are responsible for knowing the university policies and resources found at
https://go.unl.edu/coursepolicies

TEXTBOOK:
B. H. Bransden and C. J. Joachain, Physics of Atoms and Molecules (Pearson Education, 2nd edition). I prefer that students have 2nd edition, but the 1st edition will be fine too.
Additional notes will be placed on Canvas, look for files text_925x...x.pdf

Prerequisites: Phys 911, 913, 914, 916, 917. Phys 918 is not required, but highly recommended. Those who have not taken Phys 917 should withdraw from the present course, unless they have obtained a permission from the instructor.

Recommended SUPPLEMENTARY BOOKS (not required):

L.D. Landau and E.M. Lifshitz, Quantum Mechanics (Pergamon, Oxford 1977 or a later edition). Contains some advanced topics on molecular spectra (based on group theory) and collision theory.

I. I. Sobelman, Introduction to the Theory of Atomic Spectra (Pergamon,1972). Good book for deep studies of atomic spectroscopy. Contains Clebsch-Gordan algebra, irreducible tensor operators and their application to the theory of atomic spectra.

G. Herzberg, Spectra of Diatomic Molecules (Van Nostrand, New York 1950) The most complete reference book (still, although now more than 70-years old!)on molecular spectra of diatomics.

C. J. Joachain, Quantum Collision Theory (North-Holland Publ., Amsterdam 1975). Electronic and atomic collisions.

D. A. Varshalovich, A. N. Moskalev and V. K. Khersonskii. Quantum Theory of Angular Momentum. (World Scientific, Singapore, 1986). The most complete reference book on the Clebsch-Gordan algebra, Wigner D-functions and related topics.

A. B. Migdal, Qualitative Methods in Quantum Theory (W.A. Benjamin Advanced Book Program, Reading, Mass. 1977). Estimate-level treatment of advanced topics in atomic theory including atomic collisions.

OUTLINE (references are to the 2nd edition of Bransden and Joachhain, with correspondent references to the 1st edition in parenthesis):

This course contains developments and applications of material covered in Phys 916 and 917. We will start with the theory of many-electron atoms, Chapter 8 (7) and their spectra, Chapter 9 (8) Then continue into the theory of molecules, Chapter 10 (9) and molecular spectra, Chapter 11 (10) which will include a brief introduction to the group theory and its application to classification of molecular energy states (notes).

The second part of the course will deal with electronic and atomic collisions whose treatment will be based on classical and quantum scattering theories covered in Phys 911 and 917. It will cover mostly Chapter 13 (12) and cursory Chapter 14 (13)

The last part of the course will deal with applications of atomic physics to quantum information (notes), astrophysics and cosmology, Sec. 16.5 (14.4) and notes, atmospheric physics (notes), industrial, fusion and astrophysical plasmas (14.3 and notes),laser physics, Sec. 15.1-15.2 (14.2), atoms in strong fields, Sec. 15.3, ultracold gases, Sec. 15.4-15.5, and physics of antimatter (notes).

These topics will be covered as short reviews, and students can choose one of them to write a term paper and make a class presentation.

COURSE OBJECTIVES:

After completing this course, students should be able to make estimates related to structure of atoms and molecules and their interactions by using methods of quantum mechanics. They should have also obtained a general knowledge of applications of atomic physics to various fields of science listed above.

HOMEWORK: specific assignments and due dates will be given on Canvas (look for files hw_925_x_23.pdf); Homework should be turned in in the handwritten form by 5 p.m. on the due date by giving it to the instructor in class (preferred method) or placing it in the instructor's

mail box, or by emailing the electronic file. Homework turned in after the due dates loses two points per day. No homework is accepted one week after the due day. In case of illness or a personal emergency new terms should be negotiated with the instructor. Note that travel (personal or professional) is not an excuse for turning in homework late.

In doing homework you are allowed to discuss problems with each other, but you are NOT allowed to cooperate on writing down the solutions on the paper.

BONUS PROBLEMS: Advanced, more difficult problems will be occasionally placed in the homework assignments. An extra credit will be given for correct solutions. This will be an opportunity to improve your grade.

EXAMS: one Midterm Exam and Final Exam. At the exams you are allowed to use the textbook and the instructor's handouts, but no other notes. Any electronic equipment except calculators, if necessary, is not allowed on the exams.

MIDTERM EXAM: 10/5, 6:00-8:00 pm (tentative)

FINAL EXAM: the official time is 7:30 to 9:30 a.m. Friday, Dec. 15

TERM PAPER: topics for term papers are listed below. A brief introduction to some topics will be presented in class. The term paper should include a literature review accompanied by ANSWERS TO SPECIFIC QUESTIONS in the term paper assignment. Plagiarism will be severely prosecuted up to the failing grade for the whole course. For getting the term paper assignment. You should approach me on INDIVIDUAL BASIS. The term paper is due on the last day of classes, but you can turn it in any time before this date, of course.

Topics for term papers

1. Quantum information and quantum computing

2. Electron, atomic and molecular collision processes in the early universe

3. Collision processes in the interstellar medium

4. Collision processes in Earth's atmospheres

5. The role of low-energy electrons in industrial and fusion plasmas

6. The role of low-energy electrons in DNA radiation damage

7. Laser cooling and trapping of neutral atoms

8. Bose-Einstein condensates

9. Degenerate Fermi gases

10. Application of the group theory to classification of vibrational spectra of polyatomic molecules

11. Application of the group theory to classification of electronic spectra of polyatomic molecules

12. Ionization of atoms in strong fields

13. Tunneling ionization of atoms and molecules

14. High-order harmonic generation in atomic gases

15. Violation of fundamental symmetries in atomic physics

16. Current status of the work on the antihydrogen production

17. Lepton collisions in antimatter studies

Grades: midterm exam - 30%; final exam - 30%; term paper - 20%; homework - 20%

Tentative grade scale:

%	grade
>96	A+
90-96	A
85-90	A-
80-85	B+
75-80	B
70-75	B-
65-70	C+
60-65	C
55-60	C-