Phys-707 Atomic and Nuclear Physics Dr. Ostrovskii Spring 2016

- **Instructor: Dr. Ostrovskii**
- **Lecture: Tu, Th 1:00 p.m. – 2:15 p.m., Room 109 Lewis Hall**
- **Office: Room 207 Lewis Hall**; Email: iostrov@phy.olemiss.edu
- **Office Hours**: **M, Th 3:30 p.m. – 4:30 p.m.**, and by appointment

TEXT: The Physics of Atoms and Quanta, by H. Haken and H.C. Wolf, 7-th edition, Springer. ISBN: 9783540208075

We will cover Chapters 1 through 20. PLEASE, READ THE TEXT

- **Additional reading**: 1) Modern Atomic and Nuclear Physics, by Fujia Yang and Joseph H. Hamilton, 2000 year edition, McGraw-Hill Companies. 2) Physics of Atoms and Molecules by B.H. Brandsen and C.J. Joachain, 2nd edition, 2003, Pearson Education Ltd., England.

1. General description of the course's purpose

- Introduce the physics graduate students to the latest achievements in Atomic and Nuclear physics.
- Present the main results of the atomic and nuclear physics in 20th and 21st centuries.
- Expand an understanding of the applications of quantum physics to the atoms and nuclei.
- Develop an understanding of contemporary atomic and nuclear physics including a broad spectrum of topics of current and emerging interest in physics.
- *Enhance the critical thinking, analytical reasoning, and problem solving skills of graduate level.*
- To give the brief sketches of some historical developments in atomic and nuclear physics in the 20th and 21st centuries.
- To use of the Internet, Interactive demos, Lecture demonstrations, and scientific publications for assuring *in-depth understanding of the matter*.
- Discuss the problems confronting physics in the 21-st century.
- Develop in learners an ability to *present orally their scientific knowledge*, which will be achieved with the help of student scientific presentations.
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2. Learning objectives of the course

In the learning objectives, we answer a question: "What will the students know and be able to do as a result of taking this class and passing the final examination."

After completing this course, a graduate student should be able to:

- Explain in detail the topics in "Modern Atomic and Nuclear Physics" including interaction of quanta with atoms, fine optical spectra, and structure of nuclei.
- Graduates will understand the latest theoretical and experimental results along with 20th/21st century developments in the field of "atomic spectroscopy."
- Graduate students will be able to apply theoretical results of Quantum physics to analysis of the experimental data on atomic and nuclear structure.
- Learners should know how to use interactive methods and Internet for their independent learning in the fields covered by this graduate course.
- The graduates will contribute to their field of study (*paragraph below*).

Different learning expectations for graduate versus undergraduate students:

- Theoretical and experimental results on "atomic and nuclear structure" will be understood at a level that helps graduate to pass a comprehensive examination and successfully accomplish their graduate research projects.
- In class, discussions of the Nobel Prizes in the fields specified will foster broad knowledge of the graduate students and especially will help them to pass an oral part of comprehensive examination.
- Doctor and Master-Science Candidates will build on their critical thinking including "how to apply contemporary results to your individual work on a dissertation/thesis."
- *Fostering independent learning* that enables the graduates to contribute to a profession or field of study: A) Graduate students will make at least one presentation of a certain section/subsection from their textbook to foster independent learning and to train teachers' skills. B) Graduates will have some

laboratory demonstrations fostering their practical experimental skills in the fields specified. C) Learners will have an opportunity to present shortly their research themes, literature reviews, etc., which enable graduates to contribute to their field of study including topics of their future dissertations/theses.

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3. Description of examinations and other student requirements

Chapter Tests and Final examination schedule:

Test # 1 (Class # 12), Chapters: 2, 3, 4, 5, 6, 8, 1 1 ------- Thursday, March 3, 2016.

Test # 2 (Class # 22), Chapters 12 – 17 --- Thursday, April 14, 2016.

FINAL EXAMINATION ------------ Thursday, May 12, Noon – 3 p.m.

Lecture and test requirements:

- Turn off your phone before class!
- It is not allowed to use of any smart devices (smartphones, programmable calculators, etc.) during exams.
- Any recording in class is in contradiction with the Copyright Law and is not permitted.
- Note taking skills should be developed. Please make your own lecture notes.
- It is articulated and stressed the role of daily class participation in the learning process.
- Absence may jeopardize your standing because you are responsible for any in-class activities**.**
- ***Academic integrity***: While in class, you are expected to attend to and participate in discussion; you are **NOT** allowed to engage in private conversation or other behaviors that would disrupt class activities. You are expected to be civil to others in the class.

Homework requirements:

- Homework is assigned after some sections are covered and is due in a week.
- Homework paper should be 8.5 x 11 inches with no torn or tattered edges.
- Homework papers should be stapled allowing their reading and grading.
- Show all your work; the answer alone is not worth anything. The answers in numbers must have **one additional digit** after a decimal point in comparison to text's "Solutions to the Problems." This additional digit will be graded as well.
- **Homework papers must include**: diagrams, equations, derivations, calculations, and explanations of what you are doing / reasoning, ***enough English*** to be understandable.
- Homework answers should have units and a reasonable number of significant digits.
- **Encircle** the answers that you want to be graded. ***(If Nothing is encircled -> Nothing is graded*)**.**

4. Information about the grading process and standards

- **GRADING SCALE**:
  - **A's ----------------- 89 – 100 (100-94 A; 89-93 A-)**
  - **B's ----------------- 79 – 88 (86-88 B+ ; 82-85 B ; 79-81 B-)**
  - **C's ------------------- 69 – 78 (76-78 C+ ; 72-75 C ; 69-71 C-)**
  - **D's ------------------- 59 – 68**
- **EVALUATION**: Grades will be based on the home works, tests, presentation, class activity and final examination; plus and minus system of A, A-, B+, B-, etc. may be applied.
- **Points**: **Home works --25 points // Two tests--- 30 points (2 chapter tests x 15 points each)**
- **Presentation --- 10 points // Class activity --- 10 points for zero university-unrelated absences, (**7 points for 1 absence; 5 - for 2 absences, 0 - for 3 absences; (- 2) points for each absence after 3**)** ***Final exam --- 25 points***
- **TOTAL = 100 points**

5. Outline of covered topics

PART 1:

Ch.1. Introduction [0.5 class]

Ch. 2. The Mass and Size of the Atom. [1.5 classes]
Determination of the Mass. Methods for Determining Avogadro's number.
Determination of the Size of the Atom. Can Individual Atoms Be Seen?

Ch. 3. Isotopes. [1 class]
The Periodic System of the Elements. Mass Spectroscopy. Modern Applications of the Mass Spectrometer. **+**SIMS.

Ch. 4. The Nucleus of the Atom. [1.5 class]
Passage of Electrons through Matter. Passage of Alpha Particles through Matter; Rutherford scattering.

Ch.5. The Photon. [1.5 class]
Wave Character of Light. Thermal Radiation.The Photoelectric Effect. The Compton Effect.

Ch. 6. The Electron. [1 class]
Production of Free Electrons. Size of the Electron. The Charge of the Electron. The Specific Charge q/m. Wave Character of Electrons and Other Particles. Interferometry with Atoms.

Ch. 7. Overview & Ch.8. Bohr's Model of the Hydrogen Atom. [2.5 classes]
Basic Principles of Spectroscopy & Optical Spectrum of the Hydrogen Atom.
Some Quantitative Conclusions. Motion of the Nucleus. Spectra of Hydrogen-like Atoms. Muonic Atoms. Excitation of Quantum Jumps by Collisions. Sommerfeld's Extension and the Experimental Justification of a Second Quantum Number. Orbital Degeneracy and the Relativistic Mass Change. Rydberg Atoms. Exotic Atoms: Positronium, Muonium, and Antihydrogen.

Ch.11. Lifting of the Orbital Degeneracy in the Spectra of Alkali Atoms. [1.5 classes]
Shell Structure. Screening. The Term Diagram. Inner Shells.

Test # 1 (Class # 12), Chapters: 2, 3, 4, 5, 6, 8, 11 ------- Thursday, March 3, 2016.

PART 2:

Ch.12. Orbital and Spin Magnetism. Fine Structure. [2.5 classes]
Magnetic Moment of the Orbital Motion. Precession and Orientation in a Magnetic Field.
Einstein-de Haas Method. Detection of Directional Quantization by Stern and Gerlach.
Fine Structure. Calculation of Spin-Orbit Splitting. Level Scheme of the Alkali Atoms.
Fine Structure in the Hydrogen Atom. The Lamb Shift.

Ch. 13. Atoms in a Magnetic Field. [1.5 classes]
Experiments and Their Semi-classical Description: Directional Quantization in a Magnetic Field. Electron Spin Resonance. The Zeeman Effect. The Vector Model. The Pashen-Back Effect. Double Resonance (+ODMR). + Giant Magneto-resistance. + Spin Microscope.

Ch. 14. Overview & Ch. 15. Atoms in an Electric Field. [2.5 classes]
Quantum theory of the Zeeman Effect. Quantum theoretical treatment of the electron and proton spins. Observation of the Stark Effect. Theory of the Stark Effect. Spin and Photon Echoes.

Ch. 16. General Laws of Optical Transitions. [1 class]
Symmetries and Selection Rules. Optical Matrix Elements. Symmetry behavior of Wave functions. Selection Rules.

Ch. 17. Many-Electron Atoms. [1.5 class]
The Spectrum of the Helium Atom. Electron Repulsion and the Pauli Principle. Angular Momentum Coupling. Russell-Saunders Coupling and *JJ* Coupling. Magnetic Moments of Many-Electron Atoms. Multiple Excitations.

Test # 2 (Class # 22), Chapters 12 – 17 --- Thursday, April 14, 2016.

PART 3:

Ch. 18. X-Ray Spectra, Internal Shells. [1.5 classes]
X-Radiation from Outer Shells. X-Ray Bremsstrahlung Spectra. Emission Line Spectra: Characteristic Radiation. Fine Structure of the X-Ray Spectra. Absorption Spectra. The Auger Effect. Photoelectron Spectroscopy (XPS), ESCA.

Ch. 19. Structure of the Periodic System. Ground States of the Elements. [1.5 classes]
Periodic System and Shell Structure. From the Electron Configuration to the Atomic Term Scheme. Atomic Ground States. Excited States of Atoms and Possible Electronic Configurations.

Ch. 20. ***Student Presentations of* Ch. 20.** Nuclear Spin, hyperfine Structure. [3 classes]
Influence of the Atomic Nucleus on Atomic Spectra. Spins and Magnetic Moments of Atomic Nuclei. The Hyperfine Interaction. Hyperfine Structure in the Ground State of the Hydrogen.

FINAL EXAMINATION ------------ Thursday, May 12, 2016, Noon – 3 p.m.

The dates of chapter tests are tentative and may be changed, but
NOT THE FINAL EXAMINATION DATE and TIME.

6. Other policies

- ***Attendance / absences***: Please bring in a **document** that explains your absence.
- **It is articulated and stressed the role of daily class participation in the learning process.**
- *Absence may jeopardize your standing because you are responsible for any in-class activities***.**
- ***Class participation***: 10 points for zero university-unrelated absences, **(**7 points for 1 absence; 5 - for 2 absences, 0 points for 3 absences; (- 2) points for each absence after 3**)**
- ***Use of electronic devices***: Please, **Turn off your phone before class!**
- ***Academic integrity***: While in class, you are expected to attend to and participate in discussion; you are **NOT** allowed to engage in private conversation or other behaviors that would disrupt class activities. You are expected to be civil to others in the class.
- ***The University of Mississippi Regulations Governing All Examinations:***
- A student's failure to appear for an examination without an acceptable excuse, inability to present valid identification, absence from the room during the course of an examination without the consent of the examiner, or attempting any portion of an examination without submitting his or her answers shall result in failure of the examination. *Tardiness beyond 15 minutes forfeits a student's right to an examination.*
- ***Last Week Policy:*** During the period of Wednesday through Friday of the last week of class, instructors are not to give exams, tests, or quizzes that contribute more than 10% of the final grade for a class.
- ***UM Attendance guidelines:*** **Faculty and staff** who supervise student organizations and teams, including NCAA sports teams, are expected to schedule competitions and performances in such a way as to minimize the number of classes that students will miss. *Names of participating students and the dates of class conflicts should be provided to the students' instructors prior to participation*. In cases where absence from class results from travel delays or the unanticipated continuation of participation in a competition, the student or supervisor should inform the instructor within one business day so that reasonable accommodations for absences due to university-sponsored activities can be made.
- ***UM Attendance guidelines:*** If a **student informs** an instructor in advance about an anticipated absence and the instructor decides not to provide an accommodation for a major exam or assessment, the student may appeal to the department chair or program director (or dean, when the instructor is chair or program director) who oversees the course. An appeal must be based on **(a)** failure of the instructor to articulate a policy, **(b)** failure of the instructor to follow the articulated policy, or **(c)** failure by the instructor to offer a reasonable accommodation for a documented absence that caused a student to miss an assessment that is **worth 20% or more of the course grade**.
- Based on UM "Class Attendance Guidelines,"**-**
- **No accommodations for missed chapter tests will be made.**
- If the instructor articulates in the syllabus the role of daily class participation in the learning process, **reasonable grade deductions can be made for absences.**