Course: Intro Quantum Mechanics II, PHYS 312
Term: Spring 2019
Room: Brockman 103
Class: MWF, 11:00-11:50

INSTRUCTOR CONTACT INFORMATION

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COURSE OBJECTIVES AND LEARNING OUTCOMES

Course Learning Objectives: In this course we will continue to introduce quantum mechanical concepts and apply them to problems in modern physics. Students will learn how to use approximate methods (perturbation theory, variational methods) to solve a variety of problems of quantum mechanics; learn how relativistic effects enter the description of the Bohr atom, and how they demonstrate themselves in multi-electron atoms; master the basics of the chemical bonding in molecules, and the structure of molecular spectra; learn scattering theory, as an important constituent of modern AMO physics. The course will end with an introduction to relativistic quantum mechanics.

Learning Outcomes: By the end of the course, students will

(1.) Understand the addition of angular momentum in QM systems, be able to compute and use Clebsch-Gordon coefficients in applications.
(2.) Understand and utilize the approximate methods of quantum mechanics, i.e. perturbation theory and variational methods, in order to solve typical problems and make effective estimates to ‘real-world’ problems in physics practice.
(3.) Master conceptually the effects of the Fermi & Bose statistics and interactions in multi-electron atoms and molecules.
(4.) Learn how light interacts with matter at the level of non-relativistic quantum mechanics, making use of time-dependent perturbation theory.
(5.) Learn scattering theory and applications to AMO physics and particle/nuclear physics.
(6.) Grasp basic ideas behind relativistic formulation of quantum mechanics and the fundamental need for a different framework (namely, quantum field theory) to fully describe relativistic quantum effects.

Detailed list of topics to be covered: (subject to revision)

1. Brief review of key concepts and the Hydrogen-atom problem
2. Addition of Angular Momenta --- Clebsch-Gordan Coefficients
3. Approximation Methods for Bound-State Problems
   3.1. Variational method.
   3.2. Perturbation theory (time independent).
   3.3. Degenerate case.
   3.4. Applications: Zeeman effect without spin. Stark effect.
4. Fine Structure of Hydrogen
   4.1. Relativistic kinematic correction.
   4.2. Spin-orbit coupling.
   4.3. Zeeman effect with spin.
5. Identical Particles
   5.1. Bosons and fermions. Pauli Exclusion Principle.
   5.2. Interaction between identical particles --- exchange term.
6. Multielectron Atoms
   6.1. Central-field approximation. Shell structure.
   6.2. Corrections to central-field approximation. Hund's rules.
7. Molecules
   7.1. Ionic and covalent bonds.
   7.2. Born-Oppenheimer approximation.
   7.3. Vibration and rotation spectra.
8. Time-Dependent Perturbation Theory
   8.1. General formalism. Harmonic case. Long-time limit.
   8.2. Fermi's Golden Rule.
   8.3. Interactions of atoms with classical electromagnetic fields.
   8.4. Adiabatic approximation. Sudden approximation.
9. Scattering Theory
   9.1. Born Approximation.
   9.2. Partial waves. Phase shifts. Optical theorem.
   9.3. Low-energy scattering: scattering length.
10. Mixed States and the Density Matrix (if time permits)
11. Brief introduction to Relativistic Quantum Physics
   11.1. Relativistic wave equations. Klein paradox.
   11.2. Free field theory. Quantized EM field; photons.

REQUIRED TEXTS AND MATERIALS

The main textbook for Phys 312 is *A Modern Approach to Quantum Mechanics*, by J.S. Townsend, 2nd edition. (ISBN 9781938787508 University Science Books) The primary resource for the course are lecture notes compiled from Paul Stevenson and Andriy Nevidomskyy. These notes will be available in the bookstore and can be used as a guide to course material.

Other textbooks you may wish to consult are listed below. There are many good books in varied styles and levels. These are some at an appropriate level for this course that have been found useful by Rice students in the past.

D.J. Griffiths, *Introduction to Quantum Mechanics*, Prentice-Hall (concise, well written)

S. Gasiorowicz, *Quantum Physics,* John Wiley & Sons (accurate and reliable, older text)

R.P. Feynman, R.B. Leighton, M. Sands, *The Feynman Lectures on Physics, Vol. 3 Quantum Mechanics*. (Unique approach, excellent on fundamentals though one could not use it as a text for a course, great to read for concepts)

ASSIGNMENTS

Weekly problem sets are assigned and due Mondays. Assignments will be made available on the course canvas page. The course will have a mid-term and final exam.

GRADE POLICIES

Final grades will be weighted 35% homework, 30% midterm exam, 30% final exam and 5% class participation. Late assignments will be penalized 20% credit per day.

RICE HONOR CODE

In this course, all students will be held to the standards of the Rice Honor Code, a code that you pledged to honor when you matriculated. If you are unfamiliar with the details of this code and how it is administered, you should consult the Honor System Handbook at http://honor.rice.edu/honor-system-handbook/. This handbook outlines the University's expectations for the integrity of your academic work, the procedures for resolving alleged violations of those expectations, and the rights and responsibilities of students and faculty members throughout the process.

Problems sets and exams in this class are covered by the honor code. For the problem sets, you are encouraged to work together and discuss subjects in the course, but you must write up your own problem sets. You should never copy the work of another student. You may not look at solution sets from previous years or solution sets found on the internet. Unlike problem sets, exams may be discussed only with the instructor and all work should be yours alone.

DISABILITY SUPPORT SERVICES

If you have a documented disability or other condition that may affect academic performance you should: 1) make sure this documentation is on file with Disability Support Services (Allen Center, Room 111 / adarice@rice.edu / x5841) to determine the accommodations you need; and 2) talk with me to discuss your accommodation needs.

SYLLABUS CHANGE POLICY

This syllabus is only a guide for the course and is subject to change with advanced notice.