PHY 308 - Quantum Physics - Spring 2017
Syllabus

Course Description: (3 credits). The concepts, historical development, and mathematical methods of quantum mechanics. Topics include Schrödinger's equation in time-dependent and time-independent forms; one- and three-dimensional solutions, including the treatment of angular momentum and spin. Applications to simple systems, especially the hydrogen atom, are stressed.

Classes: Tuesdays and Thursdays 8:30-9:50 AM, ESS 131.
Instructor: Prof. Thomas K. Allison <thomas.allison@stonybrook.edu>
Instructor Office Hours: Tuesdays and Wednesdays, 1:00-2:30 PM in Chem 579.
Teaching Assistant: Andrew Jamieson <andrew.jamieson@stonybrook.edu>.
Teaching Assistant Office Hours: TBD

Course Objectives: Students will acquire knowledge of the core aspects of quantum mechanics. Students will gain the ability to solve the Schrödinger equation for simple systems, add spin and orbtial angular momenta, and construct many-particle wave functions. Most importantly, through rigorous problem solving, students will gain an intuition for quantum phenomena.

Course Website: On Blackboard
Course Textbook: *Introduction to Quantum Mechanics, 2nd ed.*, by David J. Griffiths
Other useful books: *Modern Quantum Mechanics* by J.J. Sakurai

Course Software: A few of the problems require you to use a computer to produce plots or perform simple computations. You are welcome to use whatever "canned" software you like to solve problems numerically, or use more low-level programming languages such as C++, Fortran, or Basic. However, your instructor is most proficient with MATLAB and thus the solutions to problems solved with computers will be published in MATLAB code along with example codes for the course. All students can access MATLAB through the university's site license http://it.stonybrook.edu/software/title/matlab.

Problem Sets: The problem set for the course is available on the course web page. Weekly assignments will be announced on Tuesdays in class (and on blackboard) and are due Thursday afternoon of the following week, before 5:00 PM. Turn in your problem sets in the box provided outside chem 579. Solutions will be posted on the course website on Fridays. Late problems will not be accepted except in extraordinary circumstances. You are encouraged to work together with your classmates on the problems, but you must turn in your own work in the end.

Although all of the problems that do not specifically say to use a computer should be tractable with pencil and paper, it is also OK to use computer-based resources for the manipulation of algebraic expressions and the evaluation of integrals or derivatives. What is important is that your problem solutions clearly explain your methodology such that someone reading them could reproduce your results. For example, if you use Mathematica or an internet resource to do a couple of lines of algebra or evaluate an integral, indicate so.

Problem sets should be clearly written, including text explaining your methodology whenever equations do not obviously lead from one to the next, and comments on computer codes. See the sample problem set solution on the course website for an example. For ease of grading, please encircle, box, or otherwise emphasize your final answers. You will find that being clear will also help you catch your mistakes.

Midterms: In class March 9 and April 18.
Final Exam: May 9 , 11:15-1:45 PM.

Approximate Grade Weighting: 35% problem sets, 30% midterm exams, 35% final exam

Ambitious Summary of Contents

Quantum Wierdness A quick overview of some strange aspects of quantum mechanics. The Stern-Gerlach experiment. Superposition and collapse. The need for complex numbers.

Wave functions and the Schrödinger Equation. The wavefunction and its absolute square: interpretation as a probability density. Time-dependent Schrödinger Equation. The Hamiltonian operator. Stationary states. Time-independent Schrödinger equation. Eigenvalue equations.

Simple One-Dimensional Systems. The time-independent Schrödinger equation for a particle moving in an arbitrary potential. The free particle. Particle in 1-dimensional box. Boundary conditions. Energy levels and quantum numbers. The classical limit. Tunneling.

Operator Formalism. Physical observables and operators. Requirements on the operators. Coordinate and linear momentum operators. Expectation values. Vector spaces and linear algebra. Basis functions and basis representations of wave functions. Heisenberg uncertainty principle. Commutators and constants of motion. Complete sets of commuting observables.

The Harmonic Oscillator. Classical introduction. Hamiltonian Operator. Solution of the Schrödinger equation. Hermite polynomials and generating functions. Solution by operator methods: creation and annihilation operators. Vibration of diatomic molecules. Aharmonicity.

Angular momentum. Rotations about different axes do not commute. Commutator relations in angular momentum and their implications. Solutions and calculations by operator methods. The rigid rotor as a model for molecular rotation. Spin. Pauli Matrices for spin-1/2 systems. Addition of angular momenta.

Hydrogen atom. Central force problems. Brief review of the solution of the Schrödinger equation for hydrogen-like atoms. Atomic orbitals. Breakdown of non-relativistic quantum mechanics for heavy atoms.

The exponential wall. The many body quantum problem. Scaling in classical and quantum mechanics. Failure of "brute-force" approach. Overview of approximation schemes.

Approximation methods. Perturbation theory: time-independent; non-degenerate and degenerate. The variational method. The Helium atom.

Quantum Mechanics of multi-particle matter The Born-Oppenheimer approximation and the concept of a potential energy surface. The hydrogen molecular cation, H_2^+. Identical particles and the symmetry of the wavefunction. The Pauli exclusion principle and the periodic table.

Electronic Structure of Solids. Bloch's theorem. The tight binding model. Free electron Fermi gas. Metals, insulators, and semiconductors.

Disability Support Services (DSS): If you have a physical, psychological, medical, or learning disability that may impact your course work, please contact Disability Support Services at (631) 632-6748 or http://studentaffairs.stonybrook.edu/dss/. They will determine with you what accommodations are necessary and appropriate. All information and documentation is confidential. Students who require assistance during emergency evacuation are encouraged to discuss their needs with their professors and Disability Support Services. For procedures and information go to the following website: http://www.sunysb.edu/ehs/fire/disabilities.shtml

Academic Integrity: Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty are required to report any suspected instance of academic dishonesty to the Academic Judiciary. For more comprehensive information on academic integrity, including categories of academic dishonesty, please refer to the academic judiciary website at http://www.stonybrook.edu/uaa/academicjudiciary

Critical Incident Management: Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of Judicial Affairs any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, and/or inhibits students' ability to learn

Electronic Communication Email to your University email account is an important way of communicating with you for this course. For most students the email address is firstname.lastname@stonybrook.edu, and the account can be accessed here: http://www.stonybrook.edu/mycloud. *It is your responsibility to read your email received at this account.* For instructions about how to verify your University email address see this: http://it.stonybrook.edu/help/kb/checking-or-changing-your-mail-forwarding-address-in-the-epo . You can set up email forwarding using instructions here: http://it.stonybrook.edu/help/kb/setting-up-mail-forwarding-in-google-mail . If you choose to forward your University email to another account, we are not responsible for any undeliverable messages.

Religious Observances: See the policy statement regarding religious holidays at

http://www.stonybrook.edu/registrar/forms/RelHolPol%20081612%20cr.pdf

Students are expected to notify the course professor by email of their intention to take time out for religious observance. This should be done as soon as possible but definitely before the end of the add/drop period. At that time they can discuss with the instructor(s) how they will be able to make up the work covered.