Course Syllabus

Course Information

PHYSICS 4301: Quantum Mechanics I
Section 001: August 23 – December 6, 2016
Classes: TR 11:30am-12:45pm in PHY 1.202

Contact Information

INSTRUCTOR: Dr. Yuri Gartstein					
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Office hours: TBA		Extra classroom hours: As needed			

Course Pre-requisites, Co-requisites, and/or Other Restrictions

Pre-requisite courses: Theoretical Physics and Linear Algebra. While some math discussions may be taking place during the course, students are advised to refresh and polish their knowledge and skills related to topics in mathematical Physics such as: complex numbers and multivariable calculus, probabilities, linear algebra and eigenvalue problems, linear differential equations and special functions (especially orthogonal polynomials), Fourier transforms and the Dirac delta-function. Variational principles and Hamilton formalism of Classical Mechanics are also particularly relevant.

Goals and Student Learning Objectives/Outcomes

This is an introductory but serious and demanding (from experience) course on Quantum Mechanics. QM is an extremely important practical tool and one of the greatest intellectual achievements of the humankind. As Michael Berry said, "... It is easy to predict that in the twenty-first century it will be quantum mechanics that influences all our lives. There is a sense in which quantum mechanics is already having profound effects... A large part of the gross national product of the industrialized countries stems from quantum mechanics". QM is undoubtedly necessary – even if not sufficient – for our understanding of the workings of the world. "Whether the goal is basic understanding or practical exploitation, learning quantum mechanics is… certainly one of the most fascinating things one can do with one's brain" (David Miller). In its quest to describe and explain the behavior of the microscopic world, QM introduced notions and pictures radically different from what we are used to in "macroscopic" classical physics of our daily existence. Famous Feynman's "No one really understands quantum physics" underlines the "counter-intuitive" and "strange" character of the quantum laws. People are still grappling with philosophical implications and interpretations of QM. Despite all of this, almost paradoxically, one can learn and start using the framework of QM quite easily. Quantitative predictions of QM are in remarkable agreement with experiments.

This instructor shares the view that it is very important to learn "how to do" quantum mechanics first, before any "intelligent" discussion of its "meaning" may take place. One of my favorite quotes in this regard is well-known "Shut up and calculate!" used by David Mermin as a brief

(and colorful!) personal summary of the Copenhagen interpretation of QM. Correspondingly, we will have this "pragmatic" focus in our journey: by learning how to ask and answer questions in QM. We won't be pursuing the historical development of the subject (please enjoy reading about this remarkable history on your own) or trying to turn it into a purely mathematical axiomatic discussion.

It would be naïve to expect that one can immediately fully internalize the "new" ideas, principles and structures. We will therefore be iteratively returning and refining them as more specific problems and examples are treated in their mathematical (and sometimes demanding) detail. As a result, I hope, many formerly "strange" things would become much more "familiar" to you. Wouldn't this be nice to be able to say "Oh, now I can *feel* why Hydrogen atom is stable"? Upon completion of the course, the instructor would like to see students indeed feeling familiar with basic notions and methods of QM – at least in the context of relatively simple systems. Another desirable outcome is further appreciation of the relationship between mathematics and physical reality and subsequent strengthening of problem-solving skills. Hence, emphasis on conceptual understanding as applied to problem solving. Students are expected to spend as much as possible of their own time on examples and problems including beyond discussions in the classroom.

Course Description

This brief high-level description is intended just to give you a glimpse of the subjects, a selection of topics from which we will be discussing (not necessarily in the same order and to different depths). More detailed subject listings will be available online.

BASIC CONCEPTS; WAVE FUNCTION AND SCHRÖDINGER EQUATION

Wave-particle duality and complementarity; The uncertainty principle and relations; Physical observables and measurements; The probabilistic interpretation and expectation values; Plane waves and wave packets; Operators of momentum and velocity; Time-dependent and time-independent Schrödinger equations; Discrete and continuum spectra; Bound and scattering states; The superposition principle and expansions of the wave function; Stationary states and conservation in QM; Time evolution of the wave function; The current density; Variational principle and formation of bound states; Transition to classical mechanics, Ehrenfest theorem.

QUANTUM MECHANICS IN ONE DIMENSION

The free particle; Delta-function potential well; Square potential well; Potential step and potential barrier; Reflection and transmission, tunneling; Harmonic oscillator, algebraic and analytic methods, coherent states; Motion in a homogeneous field.

FORMALISM

Hilbert space and state vectors; Linear operators, their commutators and uncertainty principle; Degeneracy and complete sets of commuting operators; Dirac notation: bra- and ket-vectors; Discrete and continuous bases; Representations of state vectors; Matrix representation of operators; Position and momentum representations; Hermitian operators, their eigenvalues and eigenvectors; Unitary transformations; Time evolution and Heisenberg picture.

QUANTUM MECHANICS IN TREE DIMENSIONS

Separation of variables; The box potential and the harmonic oscillator; Spherically-symmetric potentials; Schrödinger equation in spherical coordinates; Orbital angular momentum, its operator, eigenfunctions and eigenvalues; Addition of angular momenta; Spherical potential well; Motion in a Coulomb field, the Hydrogen atom and its spectrum; Spin; Spin-1/2 and Pauli matrices; Electron spin in magnetic field; Dynamics of a two-level system and Larmor precession; Stern-Gerlach experiment.

Textbooks and Materials

This course is *not going* to follow the exposition in a single specific textbook - so your lecture notes are expected to be a helpful resource in relating to your reading materials. There are many, "old" and "new", wonderful books that cover various aspects of quantum mechanics essentials and in different styles. Depending on student's personal demands and aesthetical preferences, he or she may find appealing different treatments. Listed below are some textbooks; they are directed towards beginners and can be adequate for our purposes.

- **"Introduction to Quantum Mechanics"** by **David Griffiths**. One of widely used and generally liked textbooks, frequently a standard at UTD. You can see that the course description above is quite similar to its list of contents. It is possible that many students decide to use this book as their main source.
- **"Quantum Mechanics for Scientists and Engineers"** by **David Miller.** A very recent and nice textbook from Stanford that has a lot of connections to modern technology applications.
- **"Quantum Mechanics. Concepts and Applications"** by **Nouredine Zettili**. A textbook that features tons of worked out examples and problems.
- **"Quantum Mechanics. An Introduction"** by **Walter Greiner**. The first book in a series by this author that represents a nice example of "German" textbook scholarship.

If you happen to have another QM textbook, it may suit you as well - do not hesitate to discuss with the instructor. I encourage students to have a good look, online and in libraries, before buying book(s).

As always, one can find particularly enriching physical discussions of many topics in

- **"The Feynman Lectures on Physics. Volume III: Quantum Mechanics"**. Absolutely enjoyable – even if "unusual" (as compared to more standard textbooks) – Feynman's way to teach elementary QM.

Assignments, Evaluation and Grading Policy

In accordance with the course objectives, conceptual understanding and ability to apply principles to actual problem solving is the key to your success. The final grade will be contributed to by the results of two exams (including final) and homework.

- The homework score will contribute approximately 50% to the final grade. The instructor believes that persistent (as opposed to sporadic) engagement with the course material is vitally important, hence a large homework contribution to stimulate such behavior. Homework assignments will be posted on eLearning and may include not only problems but also self-study topics. The homework must be submitted by the due date but extra specified time will be given to provide improved solutions. Consistent performance here can therefore build a foundation for a satisfying final grade.
- Midterm and final written exams, each contributing about 25% to the final grade, consist of problems, no multiple choice questions will be given. At instructor's discretion, the exams may take place either in the classroom or in the take-home mode. When in the classroom, exams are open book. In all cases, a student **should be able** to explain his/her solutions. The **final exam** is on the UTD schedule (TBA).
- Select questions/problems/topics including from homework may be discussed in class with individual students asked to present, lead and participate in such discussions. The instructor

reserves up to 10% of the final grade as bonus points to reward meaningful student contributions. The corollary here is that one would like to be always prepared.

Course & Instructor Policies

Every attempt will be made to give students an opportunity to improve their standing. As mentioned above, this includes the possibility to resubmit homework assignments. Results of exams are open for individual discussions. All questions about grades should be addressed the same week the grades become known. All special student needs should be reported within first two weeks of the course. Communication of all grades and announcements will be through eLearning, it is the **responsibility of students** to regularly check their eLearning pages and email.

A proactive student's position in and out of the classroom is encouraged and expected, and your feedback is always welcome. Attendance of lectures is strongly advised but not required. The integrity of students' behavior matters - working in groups and using various materials is encouraged but it is the individual understanding of the subject and results that will be tested.

Last but not least, the instructor strongly feels that satisfaction one gets from the learning accomplishments makes "grades" a much less sensitive issue. My general position is that "I am here not to make your life harder but to help you learn". I would like to invite all students to have more fun from learning and worry less about grading.

Off-campus Instruction and Course Activities

Off-campus, out-of-state, and foreign instruction and activities are subject to state law and University policies and procedures regarding travel and risk-related activities. Information regarding these rules and regulations may be found at the website address http://www.utdallas.edu/BusinessAffairs/Travel_Risk_Activities.htm. Additional information is available from the office of the school dean.

Student Conduct & Discipline

The University of Texas System and The U. T. Dallas have rules and regulations for the orderly and efficient conduct of their business. It is the responsibility of each student and each student organization to be knowledgeable about the rules and regulations which govern student conduct and activities. General information on student conduct and discipline is contained in the UTD publication, *A to Z Guide*, which is provided to all registered students each academic year. The U. T. Dallas administers student discipline within the procedures of recognized and established due process. Procedures are defined and described in the *Rules and Regulations, Board of Regents, The University of Texas System, Part 1, Chapter VI, Section 3*, and in Title V, Rules on Student Services and Activities of the university's *Handbook of Operating Procedures*. Copies of these rules and regulations are available to students in the Office of the Dean of Students, where staff members are available to assist students in interpreting the rules and regulations (SU 1.602, 972/883-6391). A student at the university neither loses the rights nor escapes the responsibilities of citizenship. He or she is expected to obey federal, state, and local laws as well as the Regents' Rules, university regulations, and administrative rules. Students are subject to discipline for violating the standards of conduct whether such conduct takes place on or off campus, or whether civil or criminal penalties are also imposed for such conduct.

Academic Integrity

The faculty expects from its students a high level of responsibility and academic honesty. Because the value of an academic degree depends upon the absolute integrity of the work done by the student for that degree, it is imperative that a student demonstrate a high standard of individual honor in his or her scholastic work. Scholastic dishonesty includes, but is not limited to, statements, acts or omissions related to applications for enrollment or the award of a degree, and/or the submission as one's own work or material that is not one's own. As a general rule, scholastic dishonesty involves one of the following acts: cheating, plagiarism, collusion and/or falsifying academic records. Students suspected of academic dishonesty are subject to disciplinary proceedings. Plagiarism, especially from the web, from portions of papers for other classes, and from any other source is unacceptable and will be dealt with under the university's policy on plagiarism (see general catalog for details).

Email Use. The U. T. Dallas recognizes the value and efficiency of communication between faculty/staff and students through electronic mail. At the same time, email raises some issues concerning security and the identity of each individual in an email exchange. The university encourages all official student email correspondence be sent only to a student's U.T. Dallas email address and that faculty and staff consider email from students official only if it originates

from a UTD student account. This allows the university to maintain a high degree of confidence in the identity of all individual corresponding and the security of the transmitted information. UTD furnishes each student with a free email account that is to be used in all communication with university personnel. The Department of Information Resources at U.T. Dallas provides a method for students to have their U.T. Dallas mail forwarded to other accounts.

Withdrawal from Class. The administration of this institution has set deadlines for withdrawal of any college-level courses. These dates and times are published in that semester's course catalog. Administration procedures must be followed. It is the student's responsibility to handle withdrawal requirements from any class. In other words, I cannot drop or withdraw any student. You must do the proper paperwork to ensure that you will not receive a final grade of "F" in a course if you choose not to attend the class once you are enrolled.

Student Grievance Procedures

Procedures for student grievances are found in Title V, Rules on Student Services and Activities, of the university's *Handbook of Operating Procedures*. In attempting to resolve any student grievance regarding grades, evaluations, or other fulfillments of academic responsibility, it is the obligation of the student first to make a serious effort to resolve the matter with the instructor, supervisor, administrator, or committee with whom the grievance originates (hereafter called "the respondent"). Individual faculty members retain primary responsibility for assigning grades and evaluations. If the matter cannot be resolved at that level, the grievance must be submitted in writing to the respondent with a copy of the respondent's School Dean. If the matter is not resolved by the written response provided by the respondent, the student may submit a written appeal to the School Dean. If the grievance is not resolved by the School Dean's decision, the student may make a written appeal to the Dean of Graduate or Undergraduate Education, and the deal will appoint and convene an Academic Appeals Panel. The decision of the Academic Appeals Panel is final. The results of the academic appeals process will be distributed to all involved parties. Copies of these rules and regulations are available to students in the Office of the Dean of Students, where staff members are available to assist students in interpreting the rules and regulations.

Incomplete Grade Policy. As per university policy, incomplete grades will be granted only for work unavoidably missed at the semester's end and only if 70% of the course work has been completed. An incomplete grade must be resolved within eight (8) weeks from the first day of the subsequent long semester. If the required work to complete the course and to remove the incomplete grade is not submitted by the specified deadline, the incomplete grade is changed automatically to a grade of **F**.

Disability Services

The goal of Disability Services is to provide students with disabilities educational opportunities equal to those of their non-disabled peers. Disability Services is located in room 1.610 in the Student Union. Office hours are Monday and Thursday, 8:30 a.m. to 6:30 p.m.; Tuesday and Wednesday, 8:30 a.m. to 7:30 p.m.; and Friday, 8:30 a.m. to 5:30 p.m.
The contact information for the Office of Disability Services is:
The University of Texas at Dallas, SU 22
PO Box 830688
Richardson, Texas 75083-0688
(972) 883-2098 (voice or TTY)
Essentially, the law requires that colleges and universities make those reasonable adjustments necessary to eliminate discrimination on the basis of disability. For example, it may be necessary to remove classroom prohibitions against tape recorders or animals (in the case of dog guides) for students who are blind. Occasionally an assignment requirement may be substituted (for example, a research paper versus an oral presentation for a student who is hearing impaired). Classes enrolled students with mobility impairments may have to be rescheduled in accessible facilities. The college or university may need to provide special services such as registration, note-taking, or mobility assistance.
It is the student's responsibility to notify his or her professors of the need for such an accommodation. Disability Services provides students with letters to present to faculty members to verify that the student has a disability and needs accommodations. Individuals requiring special accommodation should contact the professor.

Religious Holy Days

The U. T. Dallas will excuse a student from class or other required activities for the travel to and observance of a religious holy day for a religion whose places of worship are exempt from property tax under Section 11.20, Tax Code, Texas Code Annotated. The student is encouraged to notify the instructor or activity sponsor as soon as possible regarding the absence, preferably in advance of the assignment. The student, so excused, will be allowed to take the exam or complete the assignment within a reasonable time after the absence: a period equal to the length of the absence, up to a maximum of one week. A student who notifies the instructor and completes any missed exam or assignment may not be penalized for the absence. A student who fails to complete the exam or assignment within the prescribed period may receive a failing grade for that exam or assignment. If a student or an instructor disagrees about the nature of the absence [i.e., for the purpose of observing a religious holy day] or if there is similar disagreement about whether the student has been given a reasonable time to complete any missed assignments or examinations, either the student or the instructor may request a ruling from the chief executive officer of the institution, or his or her designee. The chief executive officer or designee must take into account the legislative intent of TEC 51.911(b), and the student and instructor will abide by the decision of the chief executive officer or designee.

These descriptions and timelines are subject to change at the discretion of the Professor.