Course Syllabus
PY451, Spring 2020
Quantum Mechanics I

Instructor: Professor Shyamsunder Erramilli
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Office hours: Tu :11:00 AM – 12:20 PM, PHO 824
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Learning Assistant: Thomas Tenzin
Grader: TBN
Lecture: TuTh 9:30 AM – 10:45 AM, **PSY B51**
Discussion: Wed 12:20 PM – 1:10 PM, **PSY B39**
Course Website: On backboard at learn.bu.edu
Lecture Material: Class notes in the form of a book are available on blackboard.

Goals for the course: Study the experimentally imposed foundational postulates of Quantum systems. Learn to solve the Schrodinger equation for non-relativistic quantum systems. Become conversant in the language of Quantum mechanics, and its place in the 21st century.

Required Textbook: Griffiths and Schroeder, *Introduction to Quantum Mechanics, 3rd edition* Cambridge University Press, 2018. Additional notes will be supplied as needed.

Supplemental Texts: No other textbook is required. Additional notes will be supplied as Lecture Notes. There are several classic textbooks on Quantum Mechanics that you should be aware of, some of which are at the Graduate level

Excellent textbooks:
- R. Shankar, *Principles of Quantum Mechanics*, Springer (1994).
- David H. McIntyre, *Quantum Mechanics*, Pearson (2012), taking a "Spin first" approach advocated by Richard Feynman, which leads of course to:
- Richard Feynman, *The Feynman Lectures on Physics*, Vol III Addison-Wesley (1965).

Some Graduate level texts:

• Cohen-Tannoudji, Diu and Laloe, *Quantum Mechanics Vol I*, Wiley (1978).
• G. Baym, *Lectures on Quantum Mechanics*, my grad school favorite, complete with cyclostyled notes.
• K. Gottfried, *Quantum Mechanics Volume I*. And there has never been the promised Volume II. A generation of older Physicists have been waiting for Godot.

• Landau and Lifschitz, *Quantum Mechanics: Nonrelativistic Theory,* 3^{rd} ed Butterworth-Heinemann. Evolutionists think that Physics has evolved over thousands of years of experiment and theory. But we Creationists know that Physics was created in Nine Volumes in 1939 by Landau and Lifschitz. All known evidence is completely consistent with the Creationist Theory of Physics.

Numerical methods:
• For numerical methods in Physics with MATLAB, Alejandro Garcia, *Numerical Methods for Physics,* 2^{nd} edition Prentice Hall (2000). A revised Python version has also been released.

Homework: Homework problems will be assigned every week. The list of problems in the homeworks serve as a 'Question Bank', and examination questions will be based closely on the homework problems. During weekly discussion sections, student "volunteers" will be called upon by the Instructor to lead the presentation of selected homework problems. Class participation and Discussion section participation, Pre-test and Post-Test will count for 5% of the course grade. Late homework will not be accepted.

Exams: There will be two mid-term exams and a final exam. No books or notes will be allowed during exams. *The second mid-term exam may be a Take-home exam that requires you to submit your solutions online, using Python Jupyter notebooks.*

PLEASE NOTE: At least 50% of the questions on the midterm and final examination will be either identical to, or based closely on, assigned homework problems that together form a 'Question Bank'. This is to encourage you to work on solving ALL the homework problems during the semester.
Grading: The course grade will be based on the following weights:
Discussion section participation - 3%
Pre-Test and Post-Test – 2% (*Full credit just for attempting*)
Homework and Quizzes - 20%
Computational Assignments (Python or MATLAB) – 10%
Midterm Exams - 40% (February and April)
Final Exam - 25%

Integrity and Honesty
All students are required to adhere to the Boston University rules and regulations regarding cheating. These rules will be strictly enforced in this class and violators will be brought before the appropriate University Committees. In particular, all exams are to be the sole work of individual students. Students may discuss with other students the various homework assignments, but each student must write up the solutions in their own words and equations. During the discussion sections, we will review the solutions of homework problems due the next week.

Course Content
PY410 is intended as the first course in a sequence of courses covering Quantum Mechanics. The goal of this course is to teach you the fundamentals of quantum mechanics with an emphasis on time-independent non-relativistic systems in one-

two- and three- dimension. It is expected that students will have had undergraduate math courses involving vector calculus and partial differential equations, at the level of the pre-requisite course PY 355, Methods of Theoretical Physics; and Modern Physics at the level of PY351 (or PY 313).

Computational exercises

You are required to learn to perform computational exercises and simulations on elementary Quantum systems and learn to report your results with clearly labeled plots and figure captions. The Physics department has transitioned to a Python-based approach in all undergraduate courses. You are encouraged to submit computational assignments in the form of Python based Jupyter notebooks. However, submissions using MATLAB or Mathematica may also be accepted, at least in the initially. There are a large number of excellent computational platforms. To keep things manageable for the course grader: For those wishing to use Mathematica or other platforms please note that although your solutions may be accepted and graded, the grader and instructors cannot provide any help and assistance. Please note that you are still required to learn Jupyter/Python by the time of the midterm examinations.

TOPICS: Chapter numbers refer to Griffiths & Schroeter

1. Experimental Foundations of Quantum Mechanics: *Quantum Weirdness.*
    a. An experiment that blew Einstein's mind (and ours too)
    b. Linearity, Superposition and Entanglement
    c. The Double Slit Experiment Chapter 1
    d. Experimental arguments for a probabilistic world
    e. The Heisenberg Uncertainty Principle
    f. Postulates of Quantum Mechanics – first draft
    g. Review of Complex numbers and Linear Algebra

2. The Schrödinger Equation, Chapter 2
    a. The Schrödinger equation in 1-D
    b. Particle in a Box
    c. Dirac Delta Function potential, bound state
    d. Finite Square Well, Bound states and Scattering states
    e. Free particle, Wave Packets
    f. 1D Harmonic Oscillator, Operator method
    g. 1D Harmonic Oscillator on a computer
    h. 1D General potential: Wag the Dog
    i. Scattering from 1D potential
    j. S-Matrix
    k. Phase shifts and Resonances

3. Hilbert Space, Hermitian Operators, Chapter 3
    a. How can the wavefunction be a vector?
    b. Dirac Notation
    c. Observables and Hermitian Operators
    d. Review of Fourier Transforms
    e. Orthonormal Basis states
    f. Postulates of Quantum Mechanics

4. Atoms Chapter 4
    a. The Schrödinger Equation in 3D
    b. Central Potentials
    c. Angular Momentum
    d. The Hydrogen Atom
    e. Spin
    f. Molecular spectroscopy