Syllabus for Physics 558a, Spring 2021

Part-I of graduate level QM at USC

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See Blackboard for assignments, posted documents, and useful links

Class times: Tu & Th 12:00-1:50 PM, Zoom link at Blackboard
Office hours: Tu & Th 3:00 – 4:00 PM, Zoom link at Blackboard

Grader: Avik Chakraborty, avikchak@usc.edu

Pre-requisites

Quantum Mechanics at undergraduate level, Classical Mechanics at graduate level, Mathematical Physics or equivalent at graduate level.

Books

Itzhak Bars, *Quantum Mechanics* (online book provided to the students)
J.J. Sakurai, *Modern Quantum Mechanics*, Addison-Wesley, 1994.
R. Shankar, *Principles of Quantum Mechanics*, 2nd Ed., Plenum Press, 1994.

Lectures & participation

We will have 28 online classes. The topic of discussion for each class (see schedule of classes below) will be closely related to prior assigned reading, however the lecture may expand in additional and/or deeper directions, depending on students' questions and interest. The students are expected to have studied the **reading material before the lecture** and should be equipped to sharpen their understanding of the topic by asking questions and getting deeper insights from the teacher's presentation. To facilitate this process, a rough agenda for each class will be as follows:

- The class will start with a 15-minute presentation by a student chosen a priori from the roster in alphabetical order. Using the **discussion board**, the student will consult with all participants before class to compile a written list of all questions on the reading material. All participants are invited to provide questions and answers before class through the discussion board or during class when the chosen student presents a **very brief summary** of the reading material and the questions and/or answers. This process should not exceed 15 minutes and should prioritize the questions & answers by the students. If there are no questions on the reading material, the student may use the remaining time to ask questions on upcoming or past homework problems.
- This will be followed by the teacher's lecture that focuses on the most essential points in that day's topic and provides answers to questions raised by the students. During the lecture some problems will be solved to illustrate how the theory is applied and the formulas are interpreted in physical examples.
- There may not be sufficient time for the lecture to cover all the assigned reading matter, but the students are expected to digest all the reading and lecture content. If there are remaining questions, the students

are responsible for bringing them up either during the office hour or during the current class or the following one.

Grading

- 30% - In class participation is expected. The goal is to generate class discussion and greater interaction among students and teacher. There are 3 components:
  10% in class 15 min. student presentations as described above.
  10% attendance (grade proportional to total minutes attended as recorded by Zoom).
  10% active participation by asking questions and/or answering them during the lectures and/or discussion board (staying quiet the entire semester loses 10 points so maximum grade becomes 90/100).

- 30% - Homework problems will be assigned approximately once per week in Blackboard. Students can share ideas but are expected to write up their own work clearly. Copying solutions from each other, from the internet or a solution manual will be considered plagiarism and will result in an automatic F grade for the course*. The homework assignments, which should be turned in by the Thursday of the following week, will be graded. The solutions will be posted in Blackboard each Thursday evening. Late homework after the answers are posted will not be accepted.
  *See: Academic Integrity Overview , Trojan Integrity Guide , Guide for Graduate Students

- 40%- One of the following. Either a 3 hr final exam, on Wednesday, May 12, 2-5 p.m., or an oral presentation and a related written assay (10 typed pages or more) on a topic of your interest in quantum mechanics connected to the material of this class (see course content below). For the latter, we will allocate 2-3 days during the exam period (May 5-12) for the whole class to be present to listen to the half-hour oral presentations of all the students (attendance required as part of participation). This choice will be decided with a vote during class on Tuesday, March 9, 2020.

Course Content

The general topic is the fundamental formulation of Quantum Mechanics and its applications in Physics. The lectures will correspond to the contents of chapters 1-7 in "Quantum Mechanics" by I. Bars, plus an additional chapter on Quantum Entanglement and Quantum Information for which handouts will be provided. Problem solving will be emphasized with extensive homework. Throughout the discussion, examples will be provided as applications in various aspects of quantum physics. The material that will be covered is listed below in broad outline. For an order of presentation see the attached schedule of lectures.

- Chap 1- Overview of Quantum Mechanics from the early stages in 1900 to the 21st Century. Semi-classical intuitive approach to QM.
- Chap. 2 - Quantum rules and their relation to classical mechanics. Moyal star product. Free and interacting systems. Translations in space and momentum. Time evolution and the Hamiltonian. Wave packets.
- Chap. 3 - General structure of quantum mechanics. Postulates, Dirac's ket-bra formalism, measurement, compatible and incompatible observables, uncertainty relation, matrix formulation of QM, general solution of a quantum problem. Some paradoxes in QM.
- Chap. 4 - Interactions. Solving the Schrodinger equation in one dimension. Piecewise continuous potentials. Harmonic oscillator and other solvable models. Using supersymmetry to solve problems. Path integrals.
- Chap. 5 - Operator methods. Harmonic oscillator, coherent states, normal ordering, fermions, general quadratic system of many particles, string as an infinite number of particles.

- Chap. 6 - Central force problem. Separation of center of mass, radial and angular operators; general properties of angular momentum, operator approach for angular momentum, spherical harmonics; radial and angular equations in d-dimensions, free particle; harmonic oscillator in 3 dimensions, degeneracy and SU(3) symmetry; Hydrogen atom.
- Chap. 7 - Properties of rotations. Lie group of rotations, representations of rotations and angular momentum, D-functions and matrices for spin j=1/2, j=1 and general j; Addition of angular momentum, reduction to irreducible representations; Clebsch-Gordan coefficients, Wigner symbols, tensor operators.
- Chap. 8 (new) – Quantum entanglement and quantum information. Einstein-Podolsky-Rosen paradox, its resolution, modern applications. Entanglement entropy, Teleportation, quantum computing. Schrodinger's Cat, Wigner's Friend, modern discussions and experiments.

Time will likely not permit to cover all the topics (see tentative schedule below). In that case a selection will have to be made among the topics that are at the end of this list. It will all depend on how quickly the topics in the first half of the list can be absorbed by the students.

Student Ombudsman

All courses in the Department of Physics & Astronomy have an assigned Student Ombudsman to serve students as a confidential, neutral, informal, and independent resource when they wish to discuss issues concerning their course without directly confronting their instructor. The Student Ombudsman for this course is: Krzysztof Pilch, pilch@usc.edu, (213) 740-1145, SSC 202.

Additional Information

Session Dates for Quantum Mechanics. Section 50626.

First day of classes: Friday, January 15, 2021
Last day of classes: Friday, April 30, 2021
Last day to add: Friday, February 5, 2021
Last day to drop without a mark of "W" and receive a refund: Friday, February 5, 2021
Last day to withdraw without a "W" on transcript or change pass/no pass to letter grade:3/5/21
Last day to drop with a mark of "W": Friday, April 30, 2021
End of session: Wednesday, May 12, 2021

Tentative Schedule of Classes and Assignments

The following schedule is and will remain work in progress. It will be modified as we go along to keep pace with the progress being made. It is essential that you review it weekly to make sure you do the correct weekly assignments.

Read the assigned material and solve the problems for the week. Students take turns (alphabetically) to provide a presentation as outlined in the syllabus. Turn in your solutions to the homework problems on the Thursday of the following week (see corresponding Blackboard link). Be prepared to present your solution of the problems during class when asked to do so by sharing your screen and answer other relevant questions.

- **Week of 01/18/2021. Lectures 1&2**
  Read QM Ch.1, all sections , begin to read Ch.2
  HW1: Solve problems Ch.1, # 6,7,8,9,10.
- **Week of 01/25/2021. Lectures 3&4**
  Read Ch.2, all sections and Ch.3, sections 3.1 – 3.4
  HW2: Solve problems Ch.2, # 1,2,4,6.
- **Week of 02/01/2021. Lectures 5&6**
  Read QM Ch.3, sections 3.5 – 3.9
  HW3: Solve problems Ch.3, # 1,5,8,10,17,18,19,20 (choose 5 out of 8).
- **Week of 02/08/2021. Lectures 7&8**
  Read QM Ch.4, sections 4.1 – 4.2.5
  HW4: Solve problems Ch.4, #.
- **Week of 02/15/2021. Lectures 9&10**
  Read QM Ch.4, sections 4.2.6 – 4.3 and Ch.5, sections 5.1 – 5.2
  HW5: Solve problems Ch.4, #.
- **Week of 02/22/2021. Lectures 11&12**
  Read QM Ch.5, section 5.3 – 5.7
  HW5: Solve problems Ch.5, #.
- **Week of 03/01/2021. Lectures 13&14**
  Read QM Ch.6, sections 6.1 – 6.5
  HW7: Solve problems Ch.6, #.
- **Week of 03/08/2021. Lectures 15&16**
  Read QM Ch.6, sections 6.5.1 – 6.8.1
  HW8: Solve problems Ch.6, #.
- **Week of 03/15/2021. Lectures 17&18**
  Read QM Ch.6, section 6.9 and Ch.7, 7.1 – 7.3
  HW9: Solve problems Ch.7, #.
- **Week of 03/22/2021, Lecture 19 (no lecture 03/23, wellness day).**
  Read QM Ch.7, sections 7.4 – 7.4.4
  HW10: Solve problems Ch.7, #.

- **Week of 03/29/2021. Lectures 20&21**
  Read QM Ch.7, sections 7.4.5 – 7.5.1
  HW11: Solve problems Ch.7, #.
- **Week of 04/05/2021. Lectures 22&23**
  Read QM Ch.7, sections 7.5.2 – 7.8
  HW12: Solve problems Ch.7, #.
- **Week of 04/12/2021. Lectures 24&25**
  Read QM Ch.8(new) Quantum Entanglement
  HW13: Solve problems (to be assigned)
- **Week of 04/19/2021. Lecture 26 (no lecture 04/22, wellness day).**
  Read QM Ch.8(new) Quantum Entanglement
  HW14: Solve problems (to be assigned)
- **Week of 04/26/2021. Lectures 27&28**
  Read QM Ch.8(new) Quantum Entanglement
  HW15: none
- **Weeks of 05/03/2021 and of 05/10/2021. Exams.**
  Final exam 3 hours (May.12, 2-5 PM)
  or Project Presentations (May.05-12, times to be decided, ½ hr allotments)