Syllabus for Physics 558a, Spring 2022

Part-I of graduate level QM at USC

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http://physics.usc.edu/~bars/

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: xxx, xxx@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 29 online lectures. The topic of discussion for each lecture is indicated in the **Schedule of Lectures** (attached). These will be closely related to assigned reading. However the lecture may expand into additional deeper directions, depending on students' questions and interest. The students should study the **reading material before the lecture** and sharpen their understanding by asking questions and getting deeper insights during the teacher's presentation. To facilitate this process, an 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** during 2-4 days before the lecture, 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. The chosen student will present a **brief outline** of the reading material while prioritizing mainly the questions and answers. This process should not exceed 15. If there are no questions on the reading material, the students 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

- 25% - In class participation is expected. The goal is to generate class discussion and greater interaction among students and teacher. There are 3 components:
  5% in class 15 min. student presentation 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 contribution to discussion in the Discussion Board (staying quiet the entire semester loses 10 points so maximum grade becomes 90/100).

- 25% - 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 and Code of Ethics

- 25% - In person midterm exam. Date Feb.28, 2022, Time 12:00-1:50 PM, Room KAP-144
- 25% - In person final exam. Date: May. 10, Time 2-4 PM, Room KAP-144

Both exams: closed book, closed notes, no smart phones or equivalent, 1 sheet (2 pages) of notes permitted.

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 Sschedule 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 list above. It will all depend on how quickly the topics in the first half of the list can be absorbed by the students.

Faculty Liason

All classes in the Department of Physics & Astronomy have an assigned Faculty Liaison 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 Faculty Liaison for this class is Dr. Vera Gluscevic, gluscevi@usc.edu, 213-740-0897, ACB 526.

Additional Information

Quantum Mechanics Section 50626, **Session Dates** (session code **001**)

First day of classes: Monday, January 9, 2023
Last day to add: Friday, January 27, 2023
Last day to change to Pass/No Pass: Friday, January 27, 2023
Last day to drop without a mark of "W" and receive a refund: Friday, January 27, 2023
Last day to withdraw without a "W" on transcript or change pass/no pass to letter grade:
Friday, February 24, 2023
Last day to drop with a mark of "W": Friday, April 7, 2023
Last day of classes: Friday, April 28, 2023
End of session: Wednesday, May 10, 2023