Syllabus
PHYS 684, Quantum Mechanics I, Fall 2022

Time: Thursday, 4:30-7:10pm
Place: Innovation Hall 330
Instructor: Erhai Zhao [ezhao.physics.gmu.edu]
Office Hour: TBD, or by appointment
Email: ezhao2@gmu.edu

Catalogue Description
Fundamental concepts of quantum mechanics, including Dirac notation, quantum dynamics, theory of angular momentum, and symmetries.

Textbook
Modern Quantum Mechanics, 3rd edition, J. J. Sakurai and J. J. Napolitano.

We will cover chapter 1 to 4 [we will skip some sections], materials from other sources will also be used.

This textbook is adopted by many physics departments across US. It emphasizes Dirac notation, and the style is very different from undergraduate texts. Some students find it intense. (You can use the 2nd edition, but be aware of the typos). There are many other excellent textbooks to choose from. For example, some students prefer *Principles of Quantum Mechanics* by R. Shankar.

Grades
Homework (40%) + Midterm Exam (30%) + Final Exam (30%).

Lectures
I will use the whiteboard most of the time. You are expected to take notes, and ask questions. If we pivot to online instruction, links to Zoom sessions will be provided in Blackboard.

Homework
Homework will appear in the Assignment folder of Blackboard with due date indicated. To submit, bring it to class on the due date [if you cannot attend, submit a single, lean pdf file by email]. The homework will be graded on a coarse scale: Excellent (5), Very Good (4), Fair (3), Absent (0).

Exam
No book, notes, or formula sheet allowed. Exam problems will be similar to homework, but some may be more challenging.

Midterm: Oct. 13 [tentative]; Final exam: Dec. 8. Both from 4:30pm to 7:10pm, at Innovation Hall 330.

Prerequisite
You are assumed to have taken an undergraduate course in Quantum Mechanics, such as PHYS 402 on the level of *Introduction to Quantum Mechanics* by Griffiths. You are also assumed to be familiar with linear algebra, vector space, differential equations, special functions (such as spherical harmonics), and in general mature math skills.

Topics [subject to change]

1. The second quantum revolution. Qubits, spins, and photons. From Stern-Gerlach experiments to quantum computers.
2. Postulates of quantum mechanics. Hilbert space, state vectors, kets, bras, and operators.
3. Eigenkets as base kets, matrix representation. Measurements, uncertainty relations. Change of basis.
4. Position, momentum and translation. Wave functions in position and momentum space.

5. Time evolution, Schrodinger equation. Spin in magnetic field. Schrodinger vs Heisenberg pictures.
6. Solving Schrodinger's wave equation, elementary cases.
7. Harmonic oscillator, creation and annihilation operators. Transition amplitudes.
8. Propagator. Feynman path integral. Potentials and gauge fields. Aharonov-Bohm effect.
9. Rotations, angular momentum operator, eigenvalues and eigenstates of angular momentum.
10. Orbital angular momentum, spherical harmonics.
11. Central potentials. Spherical potential well, 3D harmonic oscillator.
12. Spin 1/2. Addition of angular momenta. spin-orbit coupling.
13. Symmetries, conservation laws, degeneracy. SO(4) symmetry, Hydrogen atom.
14. Discrete symmetries: spatial inversion, reflection, lattice translation, time-reversal.
15. Density matrix, pure and mixed ensembles [Chapter 3.4].
16. Bell states, EPR, entanglement and teleportation [Chapter 3.10].

- Topics in color are optional and will be covered if time permits and upon students' request.
- A few sections will be omitted, e.g. on WKB approximation (chapter 2.5.4, which I believe belongs to Quantum II along with other approximation methods) and tensor operators (chapter 3.11).
- The coverage of some technical sections will be condensed to make room for in-depth discussion on the fundamentals.

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