Physics 423 Quantum Mechanics I
Lehigh University, Spring 2024

Instructor: Ariel Sommer
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Office hours: TBA
Class: Tues/Thurs 12:10 – 1:25 pm
Room: Lewis 511

Course Overview
The first course in a two-semester sequence on quantum mechanics at the graduate level. This course reviews the basic structure and applications of quantum mechanics while introducing some more advanced concepts.

Textbooks:
- Sakurai and Napolitano, *Modern Quantum Mechanics*, 3rd ed., Cambridge, 2021
- Zettili, *Quantum Mechanics: Concepts and Applications*, 3rd ed., Wiley, 2022

Additional reference (both free online through Lehigh library)
- Ballentine, *Quantum mechanics: a modern development*, World Scientific, 2015
- Mathur and Singh, Concepts in quantum mechanics, CRC 2008

Course Outline
- Ch 1: Fundamentals of quantum mechanics
  - Bra-ket notation, state vectors, operators, generalized uncertainty principle
  - Momentum and translation operators, wavefunctions
- Ch 2: Dynamics
  - Schrodinger equations, Heisenberg picture
  - Harmonic oscillator, solutions to Schrodinger wave equations
- Ch 3: Angular momentum and rotation
  - Rotation operators, angular momentum algebra and eigenstates
  - Orbital angular momentum, central potentials, and hydrogen atom
  - Addition of angular momentum, Clebsch-Gordan coefficients

Homework: Homework will be assigned weekly. You are expected to turn in homework on time. You may work together on the homework, but make sure that you are able to complete the problems on your own. The work you turn in must be your own.

Late homework: Please contact me if you would like to request an extension due to illness or other circumstances.

Exams: The course will have two midterm exams, plus a final exam.

Grading: Final grades in the course will be based on homework (40%), midterms (30%), and the final exam (30%).

Learning Outcomes:
Students will learn the following skills.
Ch 1:

- Apply the postulates of quantum mechanics to describe quantum systems using state vectors, and calculate measurement probabilities
- Calculate the eigenstates and eigenvalues of observables
- Convert between matrix and bra-ket representations of state vectors and operators
- Determine whether two observables are compatible and apply the uncertainty principle
- Apply a change of basis to a representation of a state vector or operator
- Understand the displacement operator and its relation to the momentum operator
- Convert between momentum-space and position-space wavefunctions

Ch 2:

- Express time evolution in terms of the time-evolution operator and Schrodinger equation
- Calculate the time-dependence of a state vector by expanding in energy eigenstates
- Calculate the time-dependence of expectation values
- Convert between the Schrodinger picture and the Heisenberg picture
- Calculate the time-dependence of operators in the Heisenberg picture
- Understand the connection between the Heisenberg picture and classical physics
- Employ ladder operators to calculate properties of harmonic oscillator systems
- Solve the Schrodinger wave equation for constant potentials
- Employ special functions to work with solutions of wave equations

Ch 3:

- Understand how rotation operators relate to angular momentum operators
- Apply rotations to spin-½ systems, employ Pauli matrices to represent observables
- Describe mixed ensembles using density operators
- Know the eigenvalues and eigenstates of general angular momentum operators
- Compute matrix representations of angular momentum operators
- Understand spherical harmonics and the radial equation for central potentials
- Non-relativistic hydrogen: understand the quantum numbers
- Know the rules of angular momentum addition
- Compute Clebsch-Gordan coefficients and employ them to solve problems
- Understand Bell's inequality for classical physics and its violation in quantum mechanics

Accommodations for Students with Disabilities: Lehigh University is committed to maintaining an equitable and inclusive community and welcomes students with disabilities into all of the University's educational programs. In order to receive consideration for reasonable accommodations, a student with a disability must contact Disability Support Services (DSS), provide documentation, and participate in an interactive review process. If the documentation supports a request for reasonable accommodations, DSS will provide students with a Letter of Accommodations. Students who are approved for accommodations at Lehigh should share this letter and discuss their accommodations and learning needs with instructors as early in the semester as possible. For more information or to request services, please contact Disability Support Services in person in Williams Hall, Suite 301, via phone at 610-758-4152, via email at indss@lehigh.edu, or online at https://studentaffairs.lehigh.edu/disabilities.

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