UC San Diego, Department of Astronomy & Astrophysics

ASTR 105, Fundamentals of Quantum Mechanics, Winter 2025

Instructor	**Lecture Info:**	**Instructor Office Hours:**
Prof. Steven Boggs (he/him) seboggs@ucsd.edu	MWF 9:00 AM - 9:50 AM 207 Center Hall	W 1:00 PM – 1:50 PM 412 SERF
GSI	**Discussion Info:**	**GSI Office Hours:**
Emily Broadbent ebroadbent@ucsd.edu	Tu 8:00 AM - 8:50 AM 201 Center Hall	TBD

Welcome to Fundamentals of Quantum Mechanics. Modern astrophysics requires quantitative knowledge of the physics governing molecular, atomic, nuclear and even particle processes, i.e., quantum mechanics. Practically, both the processes across the cosmos producing radiation and the instruments we develop on Earth to detect that radiation are inherently quantum in nature. Fundamentally, insight into the structure and dynamics of astrophysical systems requires a deep understanding of processes at the microscopic level. Quantum mechanics is intrinsic to all modern fields of astrophysics.

Course Website: http://canvas.ucsd.edu/
The website includes course materials and information, a link to Gradescope for homework submission, useful links and references, and important course notices.

Learning Goals: My goals for the course are:
- Learn mathematical techniques for solving the wave equation and calculating outcomes of measurements.
- Understand the relation between operators and observables, their relation to eigenstates and eigenvalues.
- Study detailed solutions to 1-D and 3-D systems.
- Use commonalities between these solutions to develop an intuitive understanding of quantum systems.
- Provide astrophysical context for these topics.

Learning Outcomes: After completion of the course, students will be able to:
- Describe the basic postulates of quantum mechanics.
- Calculate eigenvalues and observable expectation values from particle wave functions.
- Solve simple 1D quantum systems (particle in a box, harmonic oscillator, free particle, barrier step).
- Anticipate qualitative features of solutions when faced with novel quantum systems.
- Solve the 3D the hydrogen atom and the free electron gas systems.

Prerequisites: ASTR 101. A good working knowledge of multivariable calculus is essential.

Course Mode: In-person lectures, problem solving in discussion, ~weekly homework, written exams.

Expectations: Students are expected to read the relevant textbook sections ahead of class, attend lecture and discussion section, review lecture notes after class, complete ~weekly assignments, and actively engage with questions and discussions in lecture, discussion section, and office hours to achieve the Learning Outcomes.

Required Text: ***Introduction to Quantum Mechanics*** (Third Edition), David J. Griffiths and Darrell F. Schroeter, Cambridge University Press, 2018. ISBN: 9781107189638. Though not specifically geared for astrophysics students, this book has become a modern standard for learning the fundamentals of quantum mechanics. We will follow most of the book closely this quarter while skipping sections not relevant for our course. Sections you can skip are listed in the weekly reading assignments, please note those when diving into your reading. We will supplement the text with material provided in lecture notes and homework assignments.

Gradescope: All homework will be assigned and collected through Gradescope which is linked on the Canvas site. Students should complete HW #0 the first week of class, which is just an exercise for verifying access to the system.

Homework: Working homework problems is central to learning the course material. You will have 8 ~weekly problem sets of approximately 5-7 problems of varying difficulty. Homework assignments will be posted on Canvas at least one week prior to the due date of the assignment. You must scan and submit your homework solutions using Gradescope. Homework solutions will be posted the morning after the homework is due. Two homework problems will be graded quantitatively (0-10) and the rest will be graded qualitatively (0-2). The choice of the two problems to grade quantitatively will be made after the homework is collected. No late homework will be accepted, but your lowest homework score will be automatically dropped.

In each problem you do over the quarter it is important to not only show your work, but also to explain the steps you are taking. We will be performing many integrations and series expansion in this course. You are welcome and encouraged to use outside resources (tables of integrals, Mathematica, Maple, SymPy, etc.) to help expedite your solutions. However, all your work needs to be shown including simplifying complex integrals to the point of facilitating use of these outside resources, and documenting the resource utilized in your solution. Failure to adequately document your detailed solution to a problem will result in partial credit. You are encouraged to work together on assignments, but each student must submit their own work.

Lectures: You are responsible for material presented in lecture that is not in the book. The complete lecture notes are provided at the start of the quarter. Lecture attendance is required and will count towards your final grade; however, students can be excused up to three (3) lecture sessions without affecting their final grade if they send an excusal request within 48 hours of missing lecture.

Grading: Your grade will be based on weekly homework sets, lecture attendance, one (1) in-class midterm exam, and a final exam:

homework	40%
midterm exam	20%
final exam	30%
lecture attendance and participation	5%
discussion section attendance and participation	5%

Homework and exams are scored on the following scale: A[85-100%], B[70-85%), C[55-70%), D[40-55%), F[<40%]. The course letter grade is determined on the same scale. Your overall homework score is the average of the seven highest problem sets. Homework is not curved. Each exam will be curved separately. As a rough guideline, typically 30% of the exams will be in the A range, 30% will be in the B range, 30-40% will be in the C range. Grades of D or F will be assigned on an individual basis for outlier performance.

Exams: The exams will include material from assigned readings and lecture notes. There will be a number of problems on each exam similar to the kinds of problems you do in homework assignments. To pass the course you must take both exams. In the event of serious personal illness or a death in the immediate family, requiring your absence from an exam, please contact me before the exam.

References: In addition to the required text, an additional text is on reserve in the Library, ***Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles*** (Second Edition), Robert Eisberg and Robert Resnick, John Wiley & Sons, 1985. ISBN: 0-471-87373-X. This book is out-of-print, but we will be utilizing excerpts of the text next quarter. Also on reserve, ***Tables of Integrals and Other Mathematical Data***, Herbert Dwight, The Macmillan Company, 1961. Also out of print, but I find it to be more easily accessible than most books of integrals.

Useful Links: Here are a few online links to tables of integrals and series expansions.
Indefinite Integrals
Definite Integrals
Series Expansions

Use of Course Materials: The materials provided by the instructor in this course including, but not limited to, lecture notes, homework assignments, solution sets, exams, exam solutions, and study materials (collectively "course materials") are for the use of the students currently enrolled in the course only. Distribution or public display of the course materials by students for non-enrolled students is not permitted, and may constitute academic misconduct under Sections 102.01, 102.05, and 102.23 of the UCSD Student Conduct Code. The course materials are also subject to copyright protection, with copyright held by the instructor. As such, the course materials may not be duplicated, distributed, publicly displayed, or modified in a manner contrary to law.

Schedule: Subject to change. Changes to this schedule will be updated on Canvas.

Week (start)	***Lecture Topics***	***GS sections (class notes)***	***HW Due***
1 (1/6)	*The Wave Function:* wave function, Schrödinger equation, observable operators and expectation values, Heisenberg's uncertainty principle	1.1-1.6 (pp. 1-14)	#0, 1/8
2 (1/13)	*Time Independent Schrödinger Equation:* stationary states, eigenfunctions and eigenvalues, infinite square well	2.1-2.2 (pp. 15-28)	#1, 1/14
3 (1/20)	**No Class 1/20** *Time Independent Schrödinger Equation:* harmonic oscillator (analytic method), tunneling, free particles and wave groups	2.3-2.4 [skip 2.3.1] (pp. 29-44)	#2, 1/21
4 (1/27)	*Time Independent Schrödinger Equation:* step potential and scattering, barrier potential, finite square well	2.5-2.6 (pp. 45-58)	#3, 1/28
5 (2/3)	*Quantum Formalism:* QM postulates, Dirac notation, superposition **In Class Midterm Friday 2/7 (class notes pp. 1-58)**	3.1-3.3 (pp. 59-64)	#4, 2/4
6 (2/10)	*Quantum Formalism:* QM postulates (cont.), operators, wave collapse, statistical interpretation, incompatible observables, uncertainty principle, time-energy uncertainty	3.4-3.6 (pp. 65-77)	
7 (2/17)	**No Class 2/17** *Quantum Mechanics in Three Dimensions:* particle in a box, spherical potentials, spherical harmonics, radial wave equation, hydrogen atom	4.1-4.2 (pp. 78-91)	#5, 2/18
8 (2/24)	*Quantum Mechanics in Three Dimensions:* hydrogen atom (cont.), hydrogen spectrum, angular momentum, Zeeman effect and electron spin	4.2-4.3 (pp. 92-105)	#6, 2/25
9 (3/3)	*Quantum Mechanics in Three Dimensions:* spin operators and eigenfunctions, singlet and triplet states *Identical Particles:* exchange operator, bosons and fermions, exclusion principle, exchange force	4.4, 5.1 [skip 4.5] (pp. 106-118)	#7, 3/4
10 (3/10)	*Identical Particles:* multi-electron atoms, degeneracy pressure **In Class Catch Up and Review Friday 3/14**	5.2-5.3 [skip 5.3.2] (pp. 119-125)	#8, 3/13
Finals (3/15)	**Final Exam Wednesday 3/19, 8:00a-10:59a, TBD**		

Weeks 3-5, ~pp. 29-39, 40-55, 55-64. Keep Monday 2/3 for finishing finite square well.