Fall 2018

Graduate Quantum Mechanics I

$$i\hbar\frac{d}{dt}|\psi(t)\rangle = \hat{H}|\psi(t)\rangle$$

Quantum mechanics provides the fundamental framework for modern physics. This course is the first semester of the department's two-semester core graduate course in quantum mechanics. In this course you will learn the basic principles of quantum mechanics, its connection to classical physics, and some of its applications.

General Information

- **Instructor**: Dr. Huaiyu "Mike" Duan, <duan@unm.edu>, P&A 1144, 505-277-1508.
- **Instructor's office hour**: You are welcome to drop by and discuss physics with me whenever my door is open. You may also send me a email to make an appointment.
- **TA**: Changhao Yi <yichanghao123@unm.edu>.
- **TA's office hour**: 2:00 – 3:00 PM on Thursday in the department lobby.
- **Lecture hours**: 9:30 – 10:45 AM on Tuesday and Thursday, P&A 184.
- **Problem session** (PHYC551.057): 5:00 – 6:30 PM on Thursday, P&A 184.
- **Main textbook**: Principles of Quantum Mechanics by R. Shankar (2nd edition, published by Springer, ISBN 978-0-306-44790-7).
- **Course homepage/repository**: UNM Learn <https://learn.unm.edu>.
- **Exam dates**: 9/20 (problem session), 10/25 (lecture), and final week.
- **Communication**: Class announcements will be sent through UNM Learn which usually go to your UNM email address, i.e. <your_unm_net_id@unm.edu>. Please check your UNM mailbox regularly during the week.

Prerequisites

- Mathematical Methods of Physics (PHYC 366) or equivalent (vector calculus, partial differential equations, complex numbers, tensor analysis, Fourier series and transforms, special functions),
- Analytical Mechanics I (PHYC 303) or equivalent,
- Intermediate Quantum Mechanics I (PHYC 491) or equivalent.

If you plan to take the second semester of this course (PHYC 522), you should have satisfied the following prerequisites by then:

- Methods of Theoretical Physics I (PHYC 466) or equivalent,
- Intermediate Quantum Mechanics II (PHYC 492) or equivalent,

- Electricity and Magnetism I (PHYC 405).

Subjects

- Math background and the postulates of quantum mechanics (Chapters 1, 3, 4),
- Simple problems in one dimension (Chapter 5),
- The classical limit and uncertainty principles (Chapters 6, 9),
- The harmonic oscillator (Chapter 7),
- Multiple degrees of freedom (Chapter 10),
- Angular momentum†, central potential, and the hydrogen atom (Chapters 12, 13),
- Path integral if time permitted (Chapter 8).

†We will discuss the concept of angular momentum in the operator approach. We will revisit it from the perspective of symmetries in the second semester.

Pedagogy

The goal of our graduate program is to equip students with the skills of a successful physicist who can learn by reading the literature and who can find and work on interesting problems to which no one knows the solutions yet. Therefore, it is very important that you cultivate a good habit of self-studying.

1. **Textbook and supplementary materials.** Study of the textbook and supplementary materials should be the PRIMARY way for you to develop understanding of the course material. The instructor will provide skeleton lecture notes to guide your reading. It is of great importance that you READ the corresponding sections of the textbook and supplemental materials BEFORE you work on homework problems. Here are a few reference books that you may also find useful:

   - Quantum Mechanics, vol. I&II, by C. Cohen-Tannoudji, B. Diu, and F. Laloë. A good textbook that requires some time to read.
   - Quantum Mechanics, by Eugen Merzbacher. A fairly comprehensive textbook organized in an unconventional order.
   - A Modern Approach to Quantum Mechanics by J. S. Townsend. This book or any of your favorite undergraduate textbooks on quantum mechanics can be useful when you find the lectures and/or the main textbook are difficult to understand.

2. **Problems.** The best way to learn a subject is by practicing. You can grasp mathematical skills and achieve deeper understanding of the subject through solving problems: the examples in the textbook, reference books, supplemental materials and lectures, and the problems in problem sessions, homework and textbooks. You are encouraged to discuss these problems with the instructor, TA and your fellow students if you have trouble solving them by yourself. But you must work out the homework problems THOROUGHLY and INDEPENDENTLY after discussing with other people. One of the ways to improve your understanding of the homework is to consult the solutions which the instructor has spent

many hours to prepare. You may gain a deeper or alternative understanding of the problems by reading the solutions even if you have solved the problems successfully.

3. **Quizzes.** Many students find their mind completely blank when they encounter a "new" problem, especially during an exam, even though they have worked hard. The way out is not to memorize everything, which is impossible, or to write everything down on the cheatsheet, which has no use if you do not know how to use it. My suggestion is to spend time pondering on and playing with the key equations until you can truly understand the physical concepts behind these equations. These equations and concepts are usually the starting point of solving a problem. You also need to keep some math tricks in you memory which may be used repeatedly in this course. To encourage you along this direction there will be several unannounced 10-minute, in-class quizzes focusing on the basic concepts and frequently used formulas. Some students may fail the course because they have developed an unhealthy habit of spending little time studying except before exams. These quizzes will check if you are on the right track and alert you before it is too late.

4. **Instructor.** The role of the instructor is to give his own perspective on the subject, which is not necessarily the same as that of the textbook, and to provide timely help and to clarify confusions. His job is best achieved when you are not shy to ask questions in and after class. There is NO DUMB QUESTION! There may be times that we have to continue the discussion in small groups after the class if the questions are relevant to only a few students.

Grades and Other Policies

1. **Homework 35% + 5% (bonus)** Please turn in EVERY homework even if you cannot finish it. The solution to each assignment will be posted in UNM Learn after the assignments have been collected. There will be NO MAKEUP HOMEWORK.

2. **Exams 20% + 20% + 25%** Exam 1 will be held during the **problem session on Thursday, 9/20**, exam 2 will the held **during the lecture (starting at 9 am) on Thursday, 10/25**, and the final exam will be held during the final week. All exams will be closed-book but you may carry a letter-sized double-sided information sheet.

3. **Quizzes 5% (bonus)** There will be NO MAKEUP QUIZ.

4. **Final letter grades** can be: A+ (≥100), A (95.0–99.9), A- (90.0–94.9), B+ (85.0–89.9), B (80.0–84.9), B- (75.0–79.9), C+ (70.0–74.9), C (65.0–69.9), C- (60.0–64.9), F (<60).

5. **Problem session:** You are strongly encouraged to register the problem session associated with this course during which we will work on homework problems together. You will receive the credit for the problem session as long as you register and show up for more than 60% of the time.