Spring 2020

Graduate Quantum Mechanics II

$$w_{fi} = \frac{2\pi}{\hbar}|V_{fi}|^2\delta(\varepsilon_f - \varepsilon_i - \hbar\omega)$$

Quantum mechanics provides the fundamental framework for modern physics. This course is the second part of the department's two-semester core graduate course on quantum mechanics. Last semester you have learned how the theory of quantum mechanics was built upon a handful postulates as well as how to solve some simple systems analytically. However, the vast majority of the problems in the real world do not have an exact analytic solution. In this semester you will learn two important tools to deal with such problems. The first one is to figure out the symmetries of the system by which much can be learned even without solving the system. The other tool is to make appropriate approximations. We will also use these tools to treat some realistic problems such as the transitions between hydrogen states and the scattering.

General Information

- **Instructor**: Dr. Huaiyu "Mike" Duan, <duan@unm.edu>, PAIS 3212.
- **Instructor's office hour**: You are welcome to drop by and discuss physics whenever my office door is open. You may also send me a email to make an appointment.
- **TA**: TBA.
- **TA's office hour**: TBA.
- **Lectures**: 9:30 10:45 AM every Tuesday and Thursday, PAIS 1140.
- **Problem sessions** (PHYC551.059): 12:30 2:00 PM every Tuesday, PAIS 1160. **Some of the problem sessions will be used for makeup lectures**.
- **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.
- **Exam dates**: 2/18, 4/7, and during the final week.
- **Communication**: Notices of the class will be announced in UNM Learn which are usually sent to your UNM email address, i.e. <your_unm_net_id@unm.edu>.

Prerequisites

- Two semesters of undergraduate Quantum Mechanics (PHYC491/492). If you have taken only one semester of undergraduate QM, you are strongly encouraged to take PHYC492 first.
- One semester of Methods of Theoretical Physics (PHYC466).
- First semester of graduate Quantum Mechanics (PHYC521).

Subjects

- Identical particles (Chapter 10),
- Space and time translation symmetries and discrete symmetries (Chapter 11),
- Local gauge symmetry and the electromagnetic potential,
- Rotational symmetry and angular momentum (Chapter 12),
- Spin (Chapter 14),
- Addition of angular momenta (Chapter 15),
- Time independent and dependent perturbation theories (Chapters 17 & 18),
- Scattering theory (Chapter 19),
- the Dirac equation (Chapter 20),
- and other extra materials if time permits.

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 difficult to understand.
2. **Problems.** The best way to learn a subject is by practicing. You will grasp mathematical skills and achieve deeper understanding of the subjects through solving problems: the examples in the textbook, reference books, supplemental materials and lectures, and the problems in the 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 the information. 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 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 the exams. These quizzes will help you 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 perspectives on the subjects, 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%** Two exams will be held during the lectures on **2/18 and 4/7**. 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. Some of the problem sessions will be used for makeup lectures. You will receive the credit for the problem session as long as you register and show up for more than 60% of the time.