PHYSICS 438a: Introduction to Quantum Mechanics

COURSE INFORMATION

Spring 2021

Course Description

Physics 438a is the first course in the introductory quantum mechanics series. It covers the foundations of quantum mechanics, including the basic postulates, the Schrödinger equation, the Born rule, Dirac notation and quantum mechanical formalism, exactly-solvable problems in 1 and 3 dimensions, spin, and identical particle statistics.

Learning Objectives

By the end of this course, you should be able to: describe the basic postulates of quantum mechanics; solve the 1D and 3D particle in a box and harmonic oscillator; solve the hydrogen atom in 3D; formally prove the uncertainty principle, Ehrenfest's theorem, and the canonical conjugation relations; and treat spin, angular momentum, and identical/distinguishable particles correctly in quantum systems.

Course Instructor

Prof. Eli Levenson-Falk (he/him)

Email address: elevenso@usc.edu

Office: SSC 222 during normal times, virtual during COVID

Student hours: Thursdays 3-4 pm and by appointment

Textbook

Introduction to Quantum Mechanics 3rd Edition, by David J. Griffiths and Darrell F. Schroeter

(Earlier editions of the same book are acceptable, but you may need a classmate's help to get homework problems assigned from the 3rd edition)

Course Logistics

We're going to be a fully online virtual course this semester, which means we'll be doing things a bit differently than normal:

- **New concepts will be introduced in short pre-recorded video mini-lectures**. I will post these ahead of time and you can watch them at your convenience, but you must watch the mini-lecture on a topic *before* we cover that topic in main lecture.
- **You must read the textbook sections we're going to cover *before* we cover them**. So

please read the textbook and watch the mini-lectures before coming to class. I'll post regular updates about which topics we're about to cover.

- **Class will be divided into 3 parts: worked examples, Q&A, and group work**. We'll play around with the ideal order and how much time to give each section, but there will be no traditional lecture. Instead, I will work out an example or two on the topics of the day; we'll have open question & answer time (with open discussion) focused on these topics; and we'll split into smaller groups for group work. The group work may include some work on homework problems. I will be moving between groups to discuss, give advice, and answer questions.
- **Homework will be longer and harder than a usual course, but partially done in class and mostly done in group work**. So there will be a lot of work, but you'll have plenty of time to do it and plenty of help to figure things out.
- **Instead of a final exam, there will be a final project**. More info on that below.

Administrativia

A. Prerequisites

Physics 304 is a prerequisite and Math 445 is a co-requisite for this course. Exceptions can be made in compelling circumstances; please contact the instructor.

B. Disabilities

Students who need to request accommodations based on a disability are required to register each semester with the Disability Services and Programs. In addition, a letter of verification to the instructor from the Disability Services and Programs is needed for the semester you are enrolled in this course. If you have any questions concerning this procedure, please contact the course instructor and Disability Services and Programs at (213) 740-0776, STU 301.

C. Academic Integrity

Students who violate university standards of academic integrity are subject to disciplinary sanctions, including failure in the course and suspension from the university. Since dishonesty in any form harms the individual, other students and the university, policies on academic integrity will be strictly enforced. The academic integrity guidelines can be found in

(i) The Trojan Integrity Guide,
http://www.usc.edu/student-affairs/SJACS/forms/tio.pdf
(ii) The Undergraduate Guide for Avoiding Plagiarism,
http:/www.usc.edu/student-affairs/SJACS/forms/tig.pdf

In plain language: don't cheat! Don't copy your answers from online, and especially don't post homework or exam problems online. We have ways of determining who posted a problem, and if we catch you doing it then you'll be reported to SJACS—no warnings, no second chances. I promise that you can get an excellent grade in this course if you do the work—just do the work!

D. Classroom Behavior

This will be an all-online semester, so classroom rules will be a bit different. Please keep your microphone muted when not speaking so that you do not add background noise. Please use headphones if possible to prevent echoes. If you feel comfortable doing so, please keep your video on. Interaction is more difficult than in person, so please be assertive in asking questions!

Any student who wants to learn quantum mechanics belongs in this course. It is the job of the instructor, the TA, and every student to ensure that this welcoming messages is felt by all students. Questions, discussion, and general interaction are strongly encouraged at all times. Hostile or unwelcoming comments or behaviors are always unacceptable and will be addressed appropriately.

E. Student Ombudsman

All courses in the Department of Physics & Astronomy have an assigned Student Ombudsman to serve students as a confidential, neutral, informal, and independent resource when they wish to discuss issues concerning their course without directly confronting their instructor. The Student Ombudsman for this course is Chris Gould, gould@usc.edu, 213-740-1101, SSC 204.

Grading

A. Grading Breakdown

Your final course grade will be based upon three major components: homework (35% of grade), midterm exam (25% of grade), and final project (40% of grade).

All students in this course will be given the same homework assignments, the same midterm, and the same final project.

B. Minimum Requirements for Passing the Course

In order to receive a passing grade in the course (D or above) you must receive a passing grade on the final project. In addition, you must turn in at least 75% of your homework assignments.

C. Homework Assignments

There will be a homework assignment every week. I expect that it will take you, in total, approximately 6 hours to complete the weekly homework (don't worry, some of this time will occur in class). These homework sets are the central way you will learn physics. Understanding physics does not mean knowing the words, having read the book. Instead, understanding implies having developed the ability to solve physics problems you have not seen before.

Homework problems will range from the trivial to the difficult. Experience shows a strong positive correlation between effort on homework and success as a student and as a physicist. So **do the homework and do it honestly.**

The counsel to do your own homework does not mean that you cannot work with other students in the class. On the contrary, **I encourage students to work together** in deciding how to solve problems. Of course, working together does not mean simply copying solutions from each other. That action is a violation of academic integrity standards. There is, however, a large

difference between simply copying and learning by cooperating. Take advantage of this opportunity. Work in groups to figure out a problem, and then **write up your own solution**.

I also understand that many solutions can be found online. However, apart from being an academic integrity violation, copying pre-existing solutions denies you an essential learning experience and this will typically result in a poor performance on exams.

Homework will be due by Blackboard submission at 11:59pm on Sundays. Handwritten homework must be scanned or photographed and uploaded as a *single* file, preferably a PDF. Many free apps exist to do this on a smartphone; I recommend CamScanner for those that use Android phones.

Solutions to the homework assignments will be posted on Blackboard shortly after the deadline. As such, **late work will NOT be accepted**. However…

I know that a student may find it impossible to complete a specific homework assignment owing to illness or other outside commitments. In order to address this issue, before computing your homework grade **I will automatically discard your two lowest homework scores**. This will happen without any special permission and no documentation will be required. This is intended to cover things like, but not limited to, illness, intercollegiate competitions (both academic and non-academic), intramural competitions, conflicts with other courses scheduling required activities outside of their declared times, and family emergencies. The only exceptions are: (i) Religious observances when documented on the web site of the Office of Religious Life, http://orl.usc.edu, in which case any affected student must inform his/her instructor of the situation no later than the day before the religious observance; (ii) Extended and well-documented medical issues.

Warning: You should view the fact that the lowest two homeworks will be dropped as a safety-net, and not as an excuse to goof-off on early homework. A student who misses an early homework for inadequate reasons, and then misses later homework for completely legitimate reasons will receive little sympathy. **You do not need to request that specific homework grades be dropped**, I will just drop the lowest two automatically.

It is very important that your written solutions are written legibly with enough details so that anybody, not just you, can understand what is going on. Specifically, be sure to show intermediate steps and **use words, not just equations, to explain the solution**. Essentially, the solution should make sense to someone who knows the material but has never seen this particular problem before. A solution consisting of a string of equations with no comments, a figure if required, or some minimal explanation will be considered unsatisfactory and graded accordingly.

The minimum threshold 75% submission rate cited in the grading criteria above applies to the homework assignment, not to the individual problem count. A partially completed written homework assignment will satisfy the requirement of submission but, for it to count, there must be some evidence of attempts at the assigned problems.

D. Examinations

There will be one Midterm Examination (Mar XX in class). The midterm exam will last 100 minutes and will be given during the normal class period.

The exam will be open-book and open-notes. Don't worry about memorizing equations; focus your efforts on understanding concepts.

Once your exam is done, you will need to take a quick photo with a smartphone and upload it to Blackboard. You will then have a period of 1 hour to get a nice scan of your exam and upload it. **Please notify me ASAP if you do not have a smartphone or other camera capable of doing this**.

Students with special examination requirements as documented by the Office of Disability Services must present their documentation to their instructor as soon after the start of classes as is possible, and certainly no later than seven calendar days prior to the first midterm, or as soon as the accommodation is granted.

E. Final Project

Instead of a final exam, a final project will be due at the end of the scheduled final exam period. For your final project you will be asked to write a number of *original* quantum mechanics problems appropriate for the level of 438a, along with detailed solutions. These should be similar in difficulty to the homework problems I assign. Each problem must cover a different topic. You will be graded on the accuracy of your solutions (50%), the appropriateness of the problem to the level of the course (25%), and the pedagogical utility of the problem (25%).

Assistance

You have a variety of opportunities for assistance available to you. Here are just some of them:

A. Classroom time

Don't underestimate the value of questions during the scheduled class period. Many students are reluctant to pose questions that they fear may seem silly to either their cohorts or the instructor. This probably includes you. Almost always, if one student asks a question, there are several others who have been bothered by the same thing. Often such questions tell me what is not clear to the students. Stopping and getting everyone together on the issue is much more useful than simply letting an explanation continue without clarification.

Classroom hours will consist mainly of group problem solving work, Q&A sessions, demos, and illustrative examples. Introduction of new material will mainly be done through pre-recorded videos and in the textbook.

B. Student Hours

For more personal attention you can come to my open student hours (held virtually on Zoom). If at all possible, come to the regularly scheduled student hours listed on the syllabus. However, if your schedule conflicts with this or you need to meet with me privately, please e-mail me to set up an appointment. Unfortunately I cannot schedule private meetings for homework help—I'd love to, but there are just too many students!

C. Study Groups

One of the most effective ways to learn new material is to teach it to others. To this end, I encourage you to work together in learning the material and in doing homework assignments.

I encourage you to discuss homework problems, approaches to solutions, and even solutions, though you are cautioned not to simply copy solutions.

You might find it useful to use the Slack channel to set up and organize discussion groups.

D. Published Solutions

Solutions to all homework sets will become available at any time after you have submitted them for grading. Looking back through the homework and reminding yourself how to solve the problems is an excellent way to study. I will also work through examples in recorded videos and during live classroom time, and will publish the solutions.

E. Other Books

There is no shortage of alternatives to the assigned textbook. Some of these will be in Leavey Library including:

- Sakurai and Napolitano, Modern Quantum Mechanics
- Shankar, Principles of Quantum Mechanics
- Thayer, Modern Introductory Quantum Mechanics with Interpretation

Electronic Assistance

A. E-mail

E-mail is the most efficient method of contacting me outside of class. You can use e-mail to make appointments to speak privately with me, to find out class logistics, or to just ask more physics questions. Important: Use your USC email account. Non-USC accounts cannot be authenticated and cannot be relied upon for any grade-affecting communication. Email from non-USC accounts may be blocked, deleted, or ignored. **Your email subject *must* include "[Physics 438a]" (including the brackets), followed by the subject of the message.** I receive a lot of spam from textbook companies, so it can be impossible to correctly categorize messages; e-mails which do not include this subject may be ignored.

I will answer e-mail within 48 hours (usually faster), except on weekends, and will answer almost any question *except* "How do I do this homework problem?" For homework help, use any of the other resources listed here! General physics questions or clarifications of an assignment are ok; occasionally a question cannot be answered easily in e-mail, in which case you will be asked to come to student hours.

B. Slack Channel

I'll be conducting most course communication (announcements, Q&A, general discussion) via the course Slack channels. I highly encourage you all to openly discuss concepts, homework problems, and any general topics you would like. You can even make a students-only channel and shut me out of it so that you can make fun of my terrible jokes in peace.

B. Course Web Site

Everyone registered in PHYS 438a should find a courses already set up within their Blackboard account (https://blackboard.usc.edu). In this lecture course you will find a copy of the syllabus, homework assignments, important news and announcements, and solutions to homeworks and exams.

SCHEDULE

WEEK	TOPICS	READING	NOTES
1 (Jan 18)	History of QM; the basic postulates; Schödinger equation and wave functions;	Griffiths Ch. 1-1.2	Why quantum? How do the basics work?
2 (Jan 25)	Probability; position and momentum; uncertainty principle	Griffiths Ch. 1 (remainder)	The universe *does* play dice
3 (Feb 1)	The time-independent Schrödinger equation; particle in an infinite square well; quantum harmonic oscillator (part 1)	Griffiths Ch. 2-2.2	Let's start solving things
4 (Feb 8)	Quantum harmonic oscillator (part 2); other exactly-solvable problems in 1D	Griffiths Ch. 2.3-2.5	The simplest problems, which is why we do our best to only ever solve these ones
5 (Feb 15)	Vector spaces; eigenstates and eigenvalues; linear algebra	Griffiths Appendix A	The advanced math that's actually way easier than the "basic" calculus
6 (Feb 22)	Hilbert space; observables; eigenstates	Griffiths Ch. 3-3.3	The FORMALISM (oooooh)
7 (Mar 1)	The uncertainty principle; commutation relations; operators; Dirac notation	Griffiths Ch. 3 (remainder)	Formalism continued; what all the funny arrows mean
Midterm Exam, March 4, in class			
8 (Mar 8)	The Schrödinger equation in 3D	Griffiths Ch. 4.1	We don't live on lines…
9 (Mar 15)	The hydrogen atom, angular momentum	Griffiths Ch. 4.2-4.3	Here's why chemistry works
10 (Mar 22)	Wellness day and special topics	None	Special stuff TBA
11 (Mar 29)	Spin, addition of angular momenta, electromagnetic fields	Griffiths Ch. 4 (remainder)	Just wait until you see what the vector potential has been up to while we were distracted

12 (Apr 5)	Identical particles, atoms, and solids	Griffiths Ch. 5	Ever wondered why stars aren't all black holes?
13 (Apr 12)	Translations; conservation laws; parity	Griffiths Ch. 6-6.4	Cool tricks you can play to bring Nöether into the 20th century
14 (Apr 19)	Rotations; degeneracies; selection rules	Griffiths Ch. 6 (remainder)	Tricks for the future
15 (Apr 26)	Review		
Final Projects Due: Tuesday, May 11, 10 am			