POINT 19 02 LOMA
NAZARENE UNIVERSITY

Department of Physics and Engineering, Point Loma Nazarene University
PHY 4053 – Quantum Mechanics (3 units) – Spring 2022

Professor: Dr. Michelle Chen
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Office Hours: TBA and by appointment

Lecture: MWF 12:15 – 1:10 pm, Rohr Science 265
Final Exam: 10:30 am – 1:00 pm, Wednesday May 4, 2022

Required Textbook and Study Resources

- Introduction to Quantum Mechanic (3rd ed.) by D.J. Griffiths and D.F. Schroeter, Cambridge University Press, 2018

Course Description: A rigorous introduction to quantum physics including Schroedinger's equation, matrix mechanics, perturbation theory, and applications in atomic and molecular physics. Prerequisite(s): MTH 2074 with a grade of C- or higher and PHY3004. Recommended MTH3033.

Learning Outcomes: In this course there are a number of specific goals for you to meet from each chapter. These smaller goals fit into the following overall learning outcomes of the physics and engineering programs to: develop an understanding of the fundamental principles of physics and of engineering; apply physical principles, mathematical reasoning, and computational techniques to solve real-world problems; analyze and interpret data; and effectively communicate complicated technical information. Once you complete this course, you should be able to:

1. apply quantum mechanical principles to several situations;
2. explain the physical meaning of the mathematical formulation
3. articulate the big ideas from each section of each chapter such as the wave function, stationary states, potential energy wells, observables, the uncertainty principle, the three-dimensional Schrödinger equation, the hydrogen atom, systems of identical particles;
4. justify and explain your thinking and approach to a problem or physical situation; and
5. sketch and interpret relevant diagrams (such as energy level diagrams or sketches of wave functions and their probabilities.)

ASSESSMENT AND GRADING

Graded Components

- **Reading:** Reading is an essential part of the course. Reading *before* class is very important. Lecture is to clarify your understanding, to help you make sense of the material. I will assume you have done the required readings in advance! Griffiths is one of the better texts I know of – it *will* make a huge difference if you spend the time and effort to carefully read and follow the text. You will briefly summarize the important points in your reading, or answer a few short questions, or

formulate questions. The assignments will be posted on CANVAS, and due at 11:59 pm the night before class. Late submissions will not be accepted. These submissions will be graded on the following scale: 2 = demonstrates reading, 1 = room for improvement, 0 = unsatisfactory. These points are accumulated and are worth 5% of the final grade. The lowest 5 scores will be dropped.

- **Homework:** Homework will be assigned on CANVAS due at the start of class on the specified date. Late homework cannot be accepted once solutions are posted. Your lowest score will be dropped. Homework is crucial for developing an understanding of course material, not to mention building skills in physical and mathematical problem solving.

  Collaboration, an essential skill in science and engineering, and highly valued by employers, is strongly encouraged. Social interactions are critical to scientists' success – most good ideas grow out of discussions with colleagues; essentially all physicists work as part of a group. Find partners and work together. However, it is also important that you OWN the material. Limit yourself to verbal help; don't take written information from others (not take written notes when you talk to others) This will ensure that you think things through independently after you get help. If you do well on homework and poorly on exams, you are probably getting too much help. In general, no credit will be given for a correct answer, unless accompanied by a complete and correct derivation. The point is not to find the answer, but to find out how to *construct* the answer. There will be time for peer discussion during classes: try to help your partners get over confusions, listen to them, ask each other questions, critique, *teach each other.* You will learn a lot this way!

- **Examinations and Final Examination:** There will be two in-class exams during the semester and one comprehensive final exam. Exams are to be taken at the time indicated in the syllabus unless other arrangements are made in advance with the professor for some unavoidable circumstance, or a well-documented emergency beyond your control, and otherwise cannot be made up. The final exam will be in the form of a research project beyond that demonstrates your comprehensive knowledge of the material, and requires writing and presentation. The final exam date and time is set by the University at the beginning of the semester and may not be changed by the instructor or student. Prior arrangements can be made only if a student has three or more final exams on the same day. You must take ***ALL*** the exams in order to pass the class. **Final Examination Policy:** Successful completion of this class requires taking the final examination **on its scheduled day (Wednesday May 4th, 2022, 10:30 am – 1:00 pm)**.

Grading Scale

- Your course grade will be based on the following:

• **Component**	• **Weight**
• Reading	• 5%
• Homework	• 30%
• Tests (2)	• 40% (equally weighted)
• Final Exam	• 25%

- **Grading Scale:** The letter grade you will earn in this course is based on the following:

Standard Grade Scale Based on Percentages

A	A-	B+	B	B-	C+	C	C-	D+	D	D-	F
S≥ 91.5	91.5 >S≥ 89.5	89.5 >S≥ 87.5	87.5 >S≥ 81.5	81.5 >S≥ 79.5	79.5 >S≥ 77.5	77.5 >S≥ 71.5	71.5 >S≥ 69.5	69.5 >S≥ 67.5	67.5 >S≥ 61.5	61.5 >S≥ 59.5	S < 59.5

FINAL EXAM

The final exam date and time is set by the university at the beginning of the semester and may not be changed by the instructor. This schedule can be found on the university website and in the course calendar. No requests for early examinations will be approved. Only in the case that a student is required to take three exams during the same day of finals week, is an instructor authorized to consider changing the exam date and time for that particular student.

CREDIT HOUR

In the interest of providing sufficient time to accomplish the stated Course Learning Outcomes, this class meets the PLNU credit hour policy for a 3-unit class delivered over 15 weeks. It is anticipated that students will spend a minimum of 37.5 participation hours per credit hour on their coursework. For this course, students will spend an estimated 150 total hours meeting the course learning outcomes. The time estimations are provided in the Canvas modules.

PLNU MISSION

To Teach ~ To Shape ~ To Send

Point Loma Nazarene University exists to provide higher education in a vital Christian community where minds are engaged and challenged, character is modeled and formed, and service is an expression of faith. Being of Wesleyan heritage, we strive to be a learning community where grace is foundational, truth is pursued, and holiness is a way of life.

DEPARTMENT MISSION

The Physics and Engineering Department at PLNU provides strong programs of study in the fields of Physics and Engineering. Our students are well prepared for graduate studies and careers in scientific and engineering fields. We emphasize a collaborative learning environment which allows students to thrive academically, build personal confidence, and develop interpersonal skills. We provide a Christian environment for students to learn values and judgment, and pursue integration of modern scientific knowledge and Christian faith.

STATE AUTHORIZATION

State authorization is a formal determination by a state that Point Loma Nazarene University is approved to conduct activities regulated by that state. In certain states outside California, Point Loma Nazarene University is not authorized to enroll online (distance education) students. If a student moves to another state after admission to the program and/or enrollment in an online course, continuation within the program and/or course will depend on whether Point Loma Nazarene University is authorized to offer distance education courses in that state. It is the student's responsibility to notify the institution of any change in his or her physical location. Refer to the map on State Authorization to view which states allow online (distance education) outside of California.

PLNU COPYRIGHT POLICY

Point Loma Nazarene University, as a non-profit educational institution, is entitled by law to use materials protected by the US Copyright Act for classroom education. Any use of those materials outside the class may violate the law.

PLNU ACADEMIC HONESTY POLICY

Students should demonstrate academic honesty by doing original work and by giving appropriate credit to the ideas of others. Academic dishonesty is the act of presenting information, ideas, and/or concepts as one's own when in reality they are the results of another person's creativity and effort. A faculty member who believes a situation involving academic dishonesty has been detected may assign a failing grade for that assignment or examination, or, depending on the seriousness of the offense, for the course. Faculty should follow and students may appeal using the procedure in the university Catalog. See Academic Policies for definitions of kinds of academic dishonesty and for further policy information.

PLNU ACADEMIC ACCOMMODATIONS POLICY

PLNU is committed to providing equal opportunity for participation in all its programs, services, and activities. Students with disabilities may request course-related accommodations by contacting the Educational Access Center (EAC), located in the Bond Academic Center (EAC@pointloma.edu or 619-849-2486). Once a student's eligibility for an accommodation has been determined, the EAC will issue an academic accommodation plan ("AP") to all faculty who teach courses in which the student is enrolled each semester.

PLNU highly recommends that students speak with their professors during the first two weeks of each semester/term about the implementation of their AP in that particular course and/or if they do not wish to utilize some or all of the elements of their AP in that course.

Students who need accommodations for a disability should contact the EAC as early as possible (i.e., ideally before the beginning of the semester) to assure appropriate accommodations can be provided. It is the student's responsibility to make the first contact with the EAC.

PLNU ATTENDANCE AND PARTICIPATION POLICY

Regular and punctual attendance at all class sessions is considered essential to optimum academic achievement. If the student is absent for more than 10 percent of class sessions, the faculty member will issue a written warning of de-enrollment. If the absences exceed 20 percent, the student may be de-enrolled without notice until the university drop date or, after that date, receive the appropriate grade for their work and participation.

CLASS ENROLLMENT

It is the student's responsibility to maintain his/her class schedule. Should the need arise to drop this course (personal emergencies, poor performance, etc.), the student has the responsibility to follow through (provided the drop date meets the stated calendar deadline established by the university), not the instructor. Simply ceasing to attend this course or failing to follow through to arrange for a change of registration (drop/add) may easily result in a grade of F on the official transcript.

SPIRITUAL CARE

Please be aware PLNU strives to be a place where you grow as whole persons. To this end, we provide resources for our students to encounter God and grow in their Christian faith.

If students have questions, a desire to meet with the chaplain or have prayer requests you can contact the Office of Spiritual Development.

PHY4053: Quantum Mechanics (Spring 2022)
(Tentative Syllabus, Subject to Updates)

Week	Dates	Topic	Reading
1	Jan. 11 - 14	1. Intro 2. Postulates of QM 3. Probability and statistics - discrete and continuous variables, average (expectation value) and sigma	1.1 - 1.3
2	Jan. 17 - 21	1. (MLK Holiday: No class) 2. Review Complex #s, classical waves and superposition, discuss "linear operators" 3. History of QM, (re) intro to Schrodinger Eq. Normalization (and more on operators)	1.4 - 1.5
3	Jan. 24 - 28	1. Operators and Eigenvalues, expectation values, sigma 2. Separation of variables 3. Infinite Square well eigenstates	1.6, 2.1 - 2.2
4	Jan. 31 - Feb. 4	1. More on infinite square well states: completeness, Fourier trick, sketching 2. Interpretation of c-n (terms in Fourier expansion of e-state) (square => probability for measuring energy E_n) 3. Harmonic oscillator - e methods!	2.2 - 2.3
5	Feb. 7 - 11	1. Harmonic oscillator by "operator methods" (and intro to commutator) 2. Wrap up operator method for HO, start free particle. 3. Free particle and Fourier Transforms	2.3 - 2.4
6 Exam 1 on Wednesday	Feb. 14 - 18	1. More on free particle, Fourier, and connection to Heisenberg uncertainty: Delta function and "orthonormality" for plane waves 2. Wrapping up free particle: interpreting phi(p) as "momentum space wave function" 3. Wrap up Fourier transforms (focus on time dependence), Probability current, Intro to "scattering" reflection and transmission	2.4 - 2.5 (we will not do the "delta function potential", but WILL cover reflection and transmission
7	Feb. 21 - 25	1. Interpreting J (current) for plane waves, Reflection and Transmission (R, T), starting Piecewise constants potentials ("step") 2. More with piecewise constant potentials ("steps" bumps", tunneling) 3. Tunneling, and intro to finite square well	2.6
8	Feb. 28 - Mar. 4	1. Finite square well (and qualitative wave function features 2. Wave function as vectors, Hilbert sapce, intro to Dirac Notation 3. Operators, Hermitian operators, the first 2 postulates of QM in detail (1) State is |psi>, 2) observable correspond to Hermitian	Wrap up Chapter 2, starting Chapter 3
9 Spring Break: No Class	Mar. 7 - 11		
10	Mar. 14 - 18	1. Determinate states, more about Hermitian operators, 3rd postulate (if measure Q, get one of the e-values) 2. 4th postulate (Probability of measuring e-value q is |<f_q| psi>|^2, where f_1 is the corresponding e-vector, and 5th postulate (when measure q, you collapse to state f_q) 3. Continuous eigenvalues (x and p iegenvectors) and the 6th postulate (Schrodinger!)	continuing in Chapter 3
11	Mar. 21 - 25	1. Generalized uncertainty principle 2. Compatible observables, Time dependence of expectation values (and energy-time uncertainty) Basically, wrapping up Chapter 3 3. Starting on 3-D!	Wrapping up Chapter 3, starting Chapter 4!
12	Mar. 28 - Apr. 1	1. Central potentials, separation of variable in r, theta, phi. Y_lm functions 2. Computing and visualizing Y_lm's, intro to radial equation and "effective 1-D like TISE" for u(R) - r R (R) 3. Angular momentum operators and commutation relations	4.1, 4.3
13 Exam 2 on Wednesday	Apr. 4 - 8	1. Angular momentum uncertainty, connecting angular momentum to angular equation in TISE: complete set of commuting observables, psi_n,l,m, (where n tell about energy, l about |L|, m about Lz) 2. Angular momentum operator methods 3. Review of angular momentum and 3D wavefunction	4.2 - 4.3
14 (No Class on Friday)	Apr. 11 - 15	1. Hydrogen radial wavefunctions 2. Hydrogen wavefunctions, energies and spectrum 3. Introdution to matrix mechanics	4.2, 3.6
15 (No Class on Monday)	Apr. 18 - 22	1. Angular momentum in matrix mechanics 2. Motivation for spin and Stern-Gerlach experiment 3. Spin eigenvectors and eigenvalues, probabilities and expectation values	4.4
16	Apr. 25 - 29	1. Review spin 2. Start on Final Research Project	
17 Final Exam on Wednesday	May 4th	Final Exam (10:30 am - 1:00 pm)	