Physics 412/512: Quantum Mechanics II

Winter 2019

- Instructor: Jay Nadeau, 370 Science Research and Teaching Center, nadeau@pdx.edu, 503-725-8929
- Office Hours: Monday, Wednesday 1-2 pm and by appointment.
- Course Website: https://d2l.pdx.edu/

Course Description
Introduction to the three-dimensional Schrodinger equation and applications such as band theory, selection rules, and molecules. The first half of the course will focus on exactly solvable models and analytic solutions. The second half will emphasize approximation methods in quantum mechanics, including perturbation theory, the variational principle, and the WKB approximation. The use of scientific software and modeling to solve quantum mechanical problems will be emphasized.

Prerequisites: Ph 411 (Quantum Mechanics I) or permission of instructor; Ph 311, 312, Mth 256. For the 512 level: PH434 (Mathematical Methods) or equivalent is strongly recommended.

Lectures: xx
Dates: xx

The required textbook for this course is *Introduction to Quantum Mechanics, 3rd Edition* by David Griffiths.

Homework: There is weekly assigned homework except during exam weeks. Exam problems will be similar to homework problems. Homework will be due before the first week's class starting Week 2. You are allowed—encouraged!—to work with others on the problem sets as long as this collaboration is acknowledged on the paper (this helps me grade; no points are deducted for collaboration).

The homework sets for PH512 will be distinct from those for PH412. Problems assigned at the graduate level will assume a level of mathematical knowledge equivalent to PH434 (e.g. the material foud in Arfken, Weber, and Harris, *Mathematical Methods for Physicists* 7th Edition chapters 1-3, 5, 6). These problem sets will emphasize the problems in the textbook rated *** (Most difficult or involved). At the 412 level, no problems rated *** will be assigned.

Numerical calculations: Part of this course will involve learning to use scientific software to perform quantum mechanical calculations. Guidance will be provided to the use of MATLAB in quantum mechanics. MATLAB is available at all computing labs on campus (except URBN) and may also be purchased individually with a large student

discount available.

Exams: There will be three exams, each covering 2 chapters. All exams will have 4 open-ended problems, for which partial credit is possible, for 25 points each. Exams are closed book but you may bring a 8.5"x11" single-sided sheet of handwritten notes with you to the exam. No electronic devices are allowed or needed. To each test bring a bluebook and a pencil. Make-up exams are not given. If you are taking the exams at the testing center, you will need to sit for the exam at the scheduled exam times.

The exams for PH512 will be different from those for 412, again assuming a greater degree of mathematical sophistication.

Exam dates and material covered
Exam 1 [Date and time]: Chapters 4,5
Exam 2 [Date and time]: Chapters 6,7
Final Exam: [Date and time]: Chapters 8,9

Grading
The grade of each exam and the course will follow this scale
A: 89-110%
A-: 85-88%
B+: 82-84%
B: 75-81%
B-: 70-74%
C+: 67-69%
C: 60-66%
C-: 55-59%;
D: 40-54%
F <40%
Depending upon the class average, the grades may be curved.

Calculating grades
Grade is calculated as Homework (30%)+ midterm 1 (20%) + midterm 2 (20%) + final (30%).

Graduate/undergraduate slash listing
This course is offered for both undergraduate (412) and graduate (512) credit. It may be taken only once. Exams and problem sets are different for each level and each level will be graded and curved separately.

How to succeed in this course

Quantum mechanics is hard. Even Einstein struggled with it. Griffiths says, "You can perform very well in this class if you follow this time-tested system":

1. Read the text section before lecture. If you read it first, it'll sink in faster during lecture.

2. Take detailed notes on your reading and *write down* questions so you can ask them in class.
3. Come to class and stay involved. Come to office hours with questions.
4. Start the homework early. Give yourself time to work and understand. No one is smart enough to do the homework in the last hour before class, and no one is smart enough to learn the material without working problems.
5. Work together. Do your own thinking, but talking to others is a great way to get unstuck.
6. Don't get behind. It's very hard to catch up.

LEARNING OBJECTIVES

1. Solve the Schrodinger equation for a variety of time-independent and time-dependent model systems in 1 and 3 dimensions.

2. Recognize when the Schrodinger equation cannot be solved exactly and apply perturbative methods to its solution.

3. Master the basics of numerical solution of the Schrodinger equation using MATLAB, Maple, or Mathematica.

4. Be able to describe selected test systems quantum mechanically, including the hydrogen atom and hydrogen molecule, the helium atom, and the electron gas.

Students taking the course at the graduate level will be expected to solve supplementary problems of greater mathematical complexity in all of the target areas.

POLICY STATEMENTS

Academic Honesty: "Academic honesty is a cornerstone of any meaningful education and a reflection of each student's maturity and integrity. The Code of Student Conduct and Responsibility, which applies to all students, prohibits all forms of academic cheating, fraud, and dishonesty. These acts include, but are not limited to: plagiarism, buying and selling of course assignments and research papers, performing academic assignments (including tests and examinations) for other persons, unauthorized disclosure and receipt of academic information, and other practices commonly understood to be academically dishonest" – Portland State University Bulletin, General Catalog Issue, Vol. 50, 2016-2017. Cheating during an exam (e.g., copying, working in teams, using additional resources such as cell phones) will result in an automatic zero and referral to the office of student affairs. A no tolerance policy will be enforced.
Absence due to sickness – Exams cannot be rescheduled. If you are ill or there is an unforeseen emergency during an exam time, please contact me as soon as feasible (phone or email). I do not take attendance otherwise.
Title IX – Portland State is committed to providing an environment free of all forms of prohibited discrimination and sexual harassment (sexual assault, domestic and dating

violence, and gender or sex-based harassment and stalking). If you have experienced any form of gender or sex-based discrimination or harassment, know that help and support are available. PSU has staff members trained to support survivors in navigating campus life, accessing health and counseling services, providing academic and on-housing accommodations, helping with legal protective orders, and more. Information about PSU's support services on campus, including confidential services and reporting options, can be found on PSU's Sexual Misconduct Prevention and Response website at: http://www.pdx.edu/sexual-assault/get-help or you may call a confidential IPV Advocate at 503-725-5672. Please be aware that all PSU faculty members and instructors are required to report information of an incident that may constitute prohibited discrimination, including sexual harassment and sexual violence. This means that if you tell me about a situation of sexual harassment or sexual violence that may have violated university policy or student code of conduct, I have to share the information with my supervisor or the University's Title IX Coordinator or the Office of Affirmative Action. For more information about Title IX please complete the required student module Creating a Safe Campus in your D2L.

Disability Accommodations at PSU – PSU values diversity and inclusion; we are committed to fostering mutual respect and full participation for all students. My goal is to create a learning environment that is equitable, useable, inclusive, and welcoming. If any aspects of instruction or course design result in barriers to your inclusion or learning, please notify me. The Disability Resource Center (DRC) provides reasonable accommodations for students who encounter barriers in the learning environment. If you have, or think you may have, a disability that may affect your work in this class and feel you need accommodations, contact the Disability Resource Center to schedule an appointment and initiate a conversation about reasonable accommodations. The DRC is located in 116 Smith Memorial Student Union, 503-725-4150, drc@pdx.edu, https://www.pdx.edu/drc.

Schedule:

Week	**Dates**	**Topics, Readings, Assignments, Deadlines**
1		Lecture 1: Intro to the course, review of time-independent Schrodinger equation, 3D Schrodinger equation (Chapter 4) Lecture 2: The hydrogen atom; angular momentum (Chapter 4)
2		Lecture 3: Bosons and fermions (Chapter 5) Lecture 4: Helium and more complex atoms (Chapter 5) **Homework 1 due: Chapter 4**
3		Lecture 5: The electron gas and band structure (Chapter 5) Lecture 6: Symmetry and the translation operator (Chapter 6) **Homework 2 due: Chapter 5**
4		**EXAM 1: Chapters 4-5** Lecture 7: Conservation laws and parity (Chapter 6)
5		Lecture 8: Rotational symmetry and selection rules (Chapter 6)

Week	Dates	Topics, Readings, Assignments, Deadlines
		Lecture 9: Nondegenerate perturbation theory (Chapter 7) **Homework 3 due: Chapter 6**
6		Lecture 10: Degenerate perturbation theory (Chapter 7) Lecture 11: Hydrogen fine structure (Chapter 7) **Homework 4 due: Chapter 7**
7		Lecture 12: Hyperfine splitting and Exam 2 review (Chapter 7) **EXAM 2: Chapters 6-7**
8		Lecture 13: The variational principle, helium (Chapter 8) Lecture 14: The variational principle, hydrogen molecule (Chapter 8) **Homework 5 due: Chapter 8**
9		Lecture 15: The WKB approximation (Chapter 9) Lecture 16: Tunneling (Chapter 9)
10		Lecture 17: **Review and recap** **Homework 6 due: Chapter 9**
Final Exam		**Chapters 8,9**