University of Wisconsin – Stevens Point

Department of Physics and Astronomy

Quantum Mechanics – PHYS 405

Spring 2024

Instructor: Maryam Farzaneh **Contact:** B105 Science Building, mfarzane@uwsp.edu

Class time: MWF 9:00 – 9:50 am, SCI-A210

Office hours: MF: 1:00 – 2:00 pm and T: 10:00 – 11:00 am

If you cannot make any of the above office hours, **please know that I have an open-door policy. Please stop by as often as you wish or make an appointment by emailing me**.

Pre-requisites: PHYS 300 (Modern Physics), Math 230 (Linear Algebra), Math 227 (Calculus III).

Textbook: *Quantum Mechanics*, David H, McIntyre, Pearson, ISBN 978-0-321-76579-6.

Required Material

- **SPINS Software:** Please visit this website:

  http://physics.oregonstate.edu/~mcintyre/ph425/spins/index_SPINS_OSP.html,

  and download the "standalone version" of the SPINS program (it is open source and free). We will use this program extensively during the first half of the semester. You need to have Java installed on your computer or laptop for the SPINS program to run. If you do not have Java, you can download the Java Runtime Environment from Oracle (JRE).

- **Calculator:** Please have a scientific calculator handy. A cell phone is *not* a scientific calculator.

- **Table of Integrals:** I will hand out a table of integrals in class (The table is also posted on Canvas). Please keep it for use in class, for your homework and during the exams.

Course Description and Objectives

You should be somewhat familiar with the historical background and basic concepts of Quantum Mechanics from what you have learned in Modern Physics (PHYS 300). In this course, we start with a very simple, completely non-classical system (spin of an electron) and learn the formalism of quantum mechanics through this simple example. We will learn a new notation (Dirac notation) and learn how to mathematically manipulate quantum mechanical state vectors. We will apply these to quantum information processing and learn about qubits, entangled states, quantum logic gates, and quantum teleportation. Next, we will generalize these methods to continuous systems and focus on solutions to the one-dimensional Schrödinger equation, including quantum harmonic oscillator. We will also work on solutions to the three-dimensional Schrödinger equation--especially the model of the hydrogen atom. Powerful mathematical tools such as linear algebra, matrix algebra and operators will be used extensively.

The **course objectives** are as follows:

1. Understand formalism of quantum mechanics through matrix mechanics and Dirac notation, as applied to simple spin systems. Apply this formalism to quantum information processing.

2. Gain an in-depth understanding of the Schrödinger equation, in one dimension.

3. Learn to solve the 3D Schrödinger equation for the hydrogen atom.

Lecture Participation and Weakly Reading Quiz

I strongly encourage you to attend *all* the lectures and take good notes. The language and concepts of Quantum Mechanics are new for most of you. The only way to master this subject is to read the text carefully (more than once) and consult other books and not solely rely on your class notes. To that effect, we will have a short (10-minute) quiz **once a week on most Mondays**. On this quiz, you will be asked to explain a concept in words and solve a very short problem. Each quiz will have 10 points and the *quiz grades count for 5% of your overall grade.*

Homework

There will be one homework set per week, which is due at the beginning of the class period on the day indicated on the assignment**. For your solutions, please follow the format summarized in the "Homework Guidelines" that I will hand out to you on the first day of class. I will not grade the homework assignments which deviate significantly from this format.**

I will post the solutions to the entire homework assignment on Canvas right after all homework assignments are submitted. **If you need an extra day or two to finish your homework, please let me know. I generally grant extensions. However, I do not accept assignments which are unreasonably late, unless you have talked to me about the situation in advance.** *Homework counts for 35% of your final grade.*

Exams

There will be *two* midterm exams during the semester, not counting your final exam. These exams will be held **on weeks 5 and 10 (please see the course schedule) in class**. The Final exam is non-cumulative and is scheduled for **Wednesday, May 15, at 12:30 – 2:30 pm**. *Overall, these three exams count for 60% of your grade (25% for each exam).*

Grading and Evaluation

I will calculate your grade based on a weighted percentage of your scores as follows:

Homework	35%
In-class Quiz	5%
Exams (2 midterms, 1 Final)	60% (20% each exam)

Your final grades will be determined as follows:

93% and above	A	87--89%	B+	77--79%	C+	67--69%	D+
90--92%	A-	83--86%	B	73--76%	C	60--66%	D
		80--82%	B-	70--72%	C-	below 60%	F

Please note that I do *not* grade on a curve. Grades will be rounded up. For example, 85.6% will become an 86% (A-), but 85.3% will remain a B+.

General Course Policies

- **Disability services**
  UWSP is committed to providing reasonable and appropriate accommodations to students with disabilities and temporary impairments. If you have a disability or acquire a condition during the semester where you need assistance, please contact the Disability Resource Center (DRC) located at 108 Collins Classroom Center (CCC) as soon as possible. DRC can be reached at 715-346-3365 or at drc@uwsp.edu.

- **Academic misconduct**
  As a student at UWSP, I expect you to be familiar with the Chapter 14 of the UWSP policy document on Academic Misconduct (especially Section 14.03) found here: https://www3.uwsp.edu/dos/Pages/Student-Conduct.aspx.

  Simply put, ***do not*** copy each other's homework, lab reports and exams and pass them off as your own. Any confirmed incidence of academic misconduct, including plagiarism and other forms of cheating will be treated seriously and in accordance with the University policy.

- **I *do not* assign work for extra credit. There are *no* bonus points that you can earn.**

- Once you hand in your final exam, there is nothing more you can do to change your grade.

Tentative Course Schedule

The tentative course schedule is as follows. This might change and I will try my best to announce any changes beforehand.

Week	Chapter and Topic	Comments
(1)	Introduction to QM, reminder and background (1) Stern-Gerlach (SG) experiment, SG experiments 1, 2, 3, 4	HW1
(2)	(1) Quantum state vectors, probabilities, analysis of Exp. 1 and 2, analysis of exp. 2, example	HW2
(3)	(1) Matrix notation, (2) Operators, eigenvalues, eigenvectors, general quantum systems, diagonalization of operators	HW3
(4)	(2) Spin in general direction, Hermitian operators, analysis of exp. 4, projection operator, measurement, expectation value, uncertainty	HW4
(5)	(2) Commuting observables, uncertainty principle, S^2 operator, spin-1 system, general spin system,	**Exam 1**
(6)	(3) Schrödinger equation, examples, stationary states with examples, spin precession	HW5
(7)	(16) Quantum Information processing, qubits, entangled states	HW6
(8)	(16) Quantum logic gates, quantum teleportation	HW7
	SPRING BREAK. NO CLASSES!	
(9)	(5) Spectroscopy, energy eigenvalue equations, wavefunction, Infinite square well	HW8
(10)	(5) Finite square well, superposition, time dependence (9) Quantum harmonic oscillators, ladder operators,	**Exam 2**
(11)	(9) Quantum harmonic oscillator's wave function, examples	HW9
(12)	(6) Free particle, energy and momentum, Dirac Delta function, wave packets: discrete superposition	HW 10
(13)	(6) Continuous superposition, Gaussian wave packet, uncertainty principle, unbound states, scattering, tunneling through barriers	HW11
(14)	(7) Energy eigenvalues in spherical coordinates (3D), angular momentum, separation of variables in spherical coordinates, associated Legendre functions, spherical harmonics and their visualization	HW12
(15)	(8) Radial eigenvalue equation and its solutions, hydrogen atom energies and spectrum, full hydrogen wave function, example	HW13
(16)	**Final Exam: Wednesday, May 15, 12:30-2:30 pm**	