University of Wisconsin – Stevens Point

Dept. of Physics and Astronomy

Quantum Mechanics – PHYS 405

Spring 2018

- **Course title:** Quantum Mechanics
- **Course number:** PHYS 405
- **Instructor:** Maryam Farzaneh
- **Contact:** B105 Science Building, x--2423, mfarzane@uwsp.edu
- **Office hours:** Mondays and Wednesdays: 10:00 – 11:00 am
  Tuesdays and Thursdays: 1:00 – 2:00 pm

  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, Math 213, Math 222.
- **Class times:**

  - Lectures (SCI- A106) TRF 10:00 – 10:50 am

Course alignment with the Physics and Astronomy department's Learning Objectives

According to some of the Department of Physics and Astronomy's Learning Objectives, when graduating from UWSP, a Physics Major will be able to

1. *Integrate conceptual reasoning, critical thinking skills, mathematical skills, and principles from both theoretical and applied physics courses to explain and solve problems related to physical processes in nature, applied mechanics, and applied electronics.* PHYS405 is a theoretical physics course, which prepares you to use critical thinking, advanced mathematical tools and principles of the theory of Quantum Mechanics to achieve problem-solving skills necessary to understand and explain many of the natural phenomena in atomic physics.

2. *Communicate effectively within the profession by writing clearly and concisely and by articulating clearly.* By following the Homework Guidelines provided to you, you should be able to express your thought process in solving problems clearly and effectively, so that anyone looking through your solution will be able to follow the steps easily.

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 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 then generalize this method to continuous systems and focus on solutions to the one-dimensional Schrödinger equation. For the rest of the course we will mostly 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.

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

3. Learn to solve the Schrödinger equation for the hydrogen atom and the quantum harmonic oscillator.

Required Material

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

- **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 and Equation Sheet:** I will hand out a table of integrals and an equation sheet in class. Please keep them for use in class, for your homework and during the exams.

Recommended Reading Material

There are many good introductory Quantum Mechanics books available at the library. Please make an effort to take a look at a few. For a great insight into quantum mechanics, I strongly recommend that you read "*Feynman Lectures in Physics, vol. III*", by Richard Feynman. The entire book is available online for free at this link: http://www.feynmanlectures.caltech.edu/III_toc.html

Lecture Participation and Quiz

I strongly encourage you to attend *all* the lectures and take good notes. The language and concepts of Quantum Mechanics is 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 or twice a week. In 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 10% 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. The solution to most of the homework problems should follow a logical step-by step approach. You should use brief sentences to describe which concepts you are using, write down any equations you are using and justify any approximation. The numerical answers should have a unit and a brief description of why it makes sense physically. Please refer to **Homework Guidelines** for more information. **.** Your homework grade is based on the completion of the assignment and the score from a few (typically four) randomly graded problems. I will post the solutions to the entire homework assignment on D2L right after the date the assignment is due. Therefore, no late homeworks are accepted. Homework counts for 24% of your final grade.

Exams

There will be *two* midterm exams during the semester, not counting your final exam. Each midterm counts for 22% of your grade. Midterm exams are tentatively scheduled for Monday February 19, and Thursday March 22, 6:00 – 8:00 pm in SCI-A107. The final exam is scheduled for **Thursday, May 17, 2:45 – 4:45 pm in SCI-A106**. It also counts for 22% of your grade.

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 and Assistive Technology Center on the 6th floor of Albertson Hall (library) as soon as possible. DATC can be reached at 715-346-3365 or DATC@uwsp.edu.

- **Academic misconduct**
  As a student at UWSP, I expect you to be familiar with the following document: http://www3.uwsp.edu/stuaffairs/Documents/RightsRespons/SRR-2010/rightsChap14.pdf, especially Section 14.03. 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 University policy.

- **Since texting and cell phone use create distraction both for me as your instructor and your classmates, they are not allowed in the classroom. All cell phones should be turned off or silenced during the class and kept in your bags. No cell phone should remain in your pockets or on your desk.**
  If I see a student texting in class, I will ask him/her to leave the classroom for the remainder of the class period.

- Make-up exam will only be accepted in the case of excused absences. Excused absences include death in the immediate family, illness with a note from the appropriate health care professional, religious observance, an event in which you officially represent the University of Wisconsin-Stevens Point and the event directly conflicts with an exam. Excused absences must be approved with documenting materials prior to the date of absence.

- If you are a student-athlete and encounter a time conflict with an exam because you have to be away for a sport competition, please make sure to approach me about the make-up exam in advance **with a note from your coach**.

- The schedule for the final exam is set by the University. I will not schedule an early final exam for whatever reason.

- **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.

Grading and Evaluation

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

Homework	24%
In-class Quiz	10%
Exams (2 midterms, 22% each)	44%
Final exam	22%

Your final grades will be determined as follows:

90% and above	A	82--85%	B+	70--73%	C+	56--60%	D+
86--89%	A-	78--81%	B	66--69%	C	50--55%	D
		74--77%	B-	61--65%	C-	below 50%	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+. **A score of 85.5% will be rounded to 85% not 86%.**

Tentative Course Schedule

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

Week	Date	Chapter and Topic	Comments
(1)	Jan 23 (T) Jan 25 (R) Jan 26 (F)	Introduction to QM, reminder and background (1) Stern-Gerlach (SG) experiment (1) SG Experiments 1, 2, 3, 4	HW1
(2)	Jan 30 (T) Feb 1 (R) Feb 2 (F)	(1) Quantum state vectors (1) Probabilities, Analysis of Exp. 1 and 2 (1) Superposition and mixed states	HW2
(3)	Feb 6 (T) Feb 8 (R) Feb 9 (F)	(1) Matrix notation, General quantum systems (2) Operators, eigenvalues, eigenvectors (2) Diagonalization of operators	HW3
(4)	Feb 13 (T) Feb 15 (R) Feb 17 (F)	(2) Spin in general direction (2) Analysis of Exp. 3 and 4 (2) Measurement, commuting observables	HW4
(5)	Feb 20 (T) Feb 22 (R) Feb 23 (F)	(2) Uncertainty Principle, S^2 operator (2) Spin-1 system (3) Schrödinger equation	**Exam 1, Monday February 19, 6:00 – 8:00 pm, A107** HW5
(6)	Feb 27 (T) March 1 (R) March 2 (F)	(3) Spin precession, magnetic field in *z*-direction (3) Time-dependent Hamiltonians, magnetic resonance (5) Spectroscopy, energy eigenvalue equations	HW6
(7)	March 6 (T) March 8 (R) March 9 (F)	(5) The wave function (5) Wave function, contd. (5) Infinite square well	HW7
(8)	March 13 (T) March 15 (R)	(5) Finite square well (5) Superposition and time dependence	HW8

	March 16 (F)	(6) Free particle eigenstates: energy and momentum	
(9)	March 20 (T) March 22 (R) March 23 (F)	(6) Free particle, contd. (6) Wave packets: discrete superposition (6) Continuous superposition	**Exam 2, Thursday March 22, 6:00 – 8:00 pm, A107**
SPRING BREAK ------- NO CLASS!			
(10)	April 3 (T) April 5 (R) April 6 (F)	(6) Uncertainty principle (6) Unbound states, scattering (6) Tunneling through barriers	HW9
(11)	April 10 (T) April 12 (R) April 13 (F)	(7) Energy eigenvalues in spherical coordinates (7) Angular momentum (7) Separation of variables in spherical coordinates	HW10
(12)	April 17 (T) April 19 (R) April 20 (F)	(7) Associated Legendre functions, spherical harmonics (7) Spherical harmonics visualization (8) Radial eigenvalue equation	HW11
(13)	April 24 (T) April 26 (R) April 27 (F)	(8) Solution to the radial equation (8) Solution to the radial equation, contd. (8) Hydrogen energies and spectrum	HW12
(14)	May 1 (T) May 3 (R) May 4 (F)	(8) Radial wave function, full hydrogen wave function (9) Classical and quantum harmonic oscillators (9) Quantum harmonic oscillator	HW13
(15)	May 8 (T) May 10 (R) May 11 (F)	(9) Quantum harmonic oscillators wave functions (9) Dirac notation, matrix representation (9) Momentum space wave function, uncertainty principle	HW14
(16)		**Final Exam: Thursday, May 17, 2:45 – 4:45 pm, A106**	