QUANTUM THEORY I

PHYS 321 Spring 2022

Instructor:	Professor David Collins
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Office Hours:	M 1:00 – 2:00pm, T 3:00 - 4:00pm, W 10:00 – 11:00am, R 2:00 - 3:00pm, F 11:00 – 12:00noon
Class Meetings:	TTh 9:30am – 10:45am, WS 366
Course Website:	http://www.coloradomesa.edu/~dacollin/teaching/2022Spring/Phys321/index.html
Required Text:	D. H. McIntyre, *Quantum Mechanics*, 1st ed., Pearson (2012).
Prerequisites:	PHYS 231, and MATH 260 or MATH 236

Overview

Quantum theory is a foundation of physics, providing a general scheme for understanding a vast range of physical phenomena. Every physicist needs to be familiar with the main ideas and results of quantum theory and many use it routinely. This course aims to give you a solid understanding of the framework and applications of quantum theory.

Quantum theory is tremendously important in our modern lifestyle; it explains the operations of semiconductors, lasers, magnetic resonance and other technologies that were inconceivable before the development of the subject. It has also profoundly changed our view of the physical world. Nearly 100 years after quantum theory was formalized, experts are still discover apparent paradoxes within the theory and dispute their implications.

In Phys 321, the general rules of quantum theory will be described using the state representation framework rather than the more limited wavefunction approach. This will be illustrated with two-state quantum systems, which have no classical counterparts but capture the essential ideas of the subject without the distracting mathematical complications associated with single particles with a position degree of freedom. The general rules will then be applied to systems with a position degree of freedom.

The course covers:

1. Spin half systems and Stern-Gerlach type experiments.
2. State representation, measurements and time evolution for spin half and analogous systems.
3. General framework of quantum mechanics.

4. Particles in one dimension: wave mechanics.
5. One dimensional harmonic oscillator.
6. Rotations and angular momentum.
7. Particles in central potentials, hydrogen atom.

Assignments

An undergraduate student should expect to spend on this course a minimum of two hours outside the classroom for every hour in the classroom. The outside hours may vary depending on the number of credit hours or type of course. More details are available from the faculty member or department office and in CMU's Curriculum Policies and Procedures Manual.

1. **Homework:** There will typically be one homework assignment per class meeting. This will be due by 5pm on the date indicated on the assignment. Late homework will be subject to a penalty of at least a 2% reduction in maximum grade for each hour that the work is late. You can discuss the broad outlines of problem solutions with your colleagues but must write your submitted solutions independently. You are also encouraged to consult me for help with homework problems.

Exams and Quizzes

1. **Class Exams:** There will be two exams during class on the following days:

Exam 1:	**3 March 2022**
Exam 2:	**21 April 2022**

   Exams will be closed book and closed notes although you will be able to bring a formula sheet. Calculators will be allowed.

2. **Final Exam:** There will be a final exam at **8:00 am on Thursday 19 May 2022**. The final will consist of a single exam done outside of class. Students will have two hours to complete the exam and submit it electronically.

Grades

Individual assignments and exams will be graded using suitable scales. In general, to get full credit (100%) for a problem your solution must be correct with complete explanations and calculations. Partial credit will be given for incomplete or partly correct solutions. No credit (0%) will be given for problems not attempted, assignments not turned in or quizzes and exams missed without good reason.

The numerical grades for each component will be totaled and a final numerical grade will be computed according to the following distribution.

Homework	40%
Class Exams	30%
Final Exam	30%

The following final numerical scores will guarantee letter grades:

90%	A
80%	B
70%	C
60%	D

Policies

1. **Helpful Resources:** The Tutorial Learning Center (TLC) is a *free* academic service for all CMU students. Tutors are available in Houston Hall 113 on a walk-in basis for many courses. More information is available at `www.coloradomesa.edu/tutoring` or 248-1392.

   In coordination with Educational Access Services, reasonable accommodations will be provided for qualified students with disabilities. Students should contact Educational Access Services (EAS) at 970-248-1856 or Houston Hall Room 108 as soon as possible. Please visit `https://www.coloradomesa.edu/educational-access` for additional information.

2. **Withdrawals:** There are several ways to drop this course. The deadline for dropping without penalty is **8 February 2022.** Please consult the CMU academic calendar and catalog for more details about adding and dropping courses.

3. **Attendance:** Attendance policies are described in the CMU catalog. You are expected to attend all the class meetings. In case of illness or other emergencies you must be able to produce the appropriate documentation. There are other circumstances under which you can be excused but you must discuss these with me in advance. If you miss a class or lab for a valid reason, turn in any assignments due before the start of the next class. Assignments turned in beyond your return to class will not be accepted.

   If there is an unavoidable conflict with one of the class exams or the final exam, please discuss it with me as soon as possible. In general I will assume that the final exam will have priority, since you know the dates of the exam.

4. **Academic integrity:** You are expected to present your own work in assignments, exams and quizzes. Fabrication of data, plagiarism, and copying from anyone else, particularly in closed book exams, are serious violation of academic norms. CMU has extensive policies on these matters and penalties for infringement can be severe. For more details, consult the academic integrity policies in the CMU catalog.

You are prohibited from using sources which provide solutions to homework assignment or exam problems. Websites which allow students to solicit solutions for homework problems will be monitored regularly for solutions to problems that have been written and produced by the course instructor or any other CMU faculty. Students who are discovered to have submitted any assignment or exam problem to any such service or have used any such service to obtain or view solutions to any assignment or exam problem will receive zero credit for that entire assignment and the instructor will submit a Report of Academic Dishonesty with the Office of Academic Affairs. Additional penalties may be levied in such cases.

Student Learning Outcomes

Upon completion of this course, a student should be able to:

1. Demonstrate an understanding of the foundations of quantum mechanics including the probabilistic formulation, wave mechanics, operators, normalization, spin, angular momentum, and algebraic methods.
2. Solve Schrödinger's equation in one, two- and three-dimensional regimes.
3. Apply formulas to generate special functions and temporal evolution of expectation values.
4. Utilize the methods of linear algebra in the solution and examination of solutions to problems in quantum mechanics.
5. Apply both the wave mechanics and algebraic formulations of quantum mechanics to physical systems.Translate between verbal and mathematical descriptions of physical situations. Apply mathematical reasoning, using algebra, trigonometry and calculus, to analyze these situations.

This course contributes to the fulfillment the following program learning objectives for the BS in Physics degree. A student will have demonstrated the ability to:

1. Show fluency with the major fields of physics (classical mechanics, electromagnetism, statistical physics and quantum theory).
2. Use mathematical representations to analyze physical scenarios. This requires translating back and forth between physical and mathematical problems and using appropriate mathematics to aid in the analysis of the scenario.

Schedule

The following schedule is tentative, except for the dates of the class exams.

Week	Dates	Topic
1	1/26 – 1/28	Spin half particles, quantum states (Ch. 1.1 – 1.2).
2	2/1 – 2/3	Quantum states, probability, linear algebra (Ch. 1.2 – 1.4).
3	2/8 – 2/10	Operators, measurements, probability (Ch. 2.1 – 2.2).
4	2/15 – 2/17	Expectation values, uncertainties (Ch. 2.2 – 2.6).
5	2/22 – 2/24	Time evolution, spin evolution (Ch. 3.1 – 3.2).
6	3/1	Spin evolution (Ch. 3.2).
6	3/3	**Exam I**.
7	3/8 – 3/10	General framework and evolution, systems in one spatial dimension (Ch. 5.1 – 5.2).
8	3/15 – 3/17	Systems in one spatial dimension, infinite well (Ch. 5.3 – 5.4).
9	3/22 – 3/24	Break (no classes).
10	3/29 – 3/31	Infinite well evolution, momentum representations, wavepackets (Ch. 5.7, 6.1).
11	4/5 – 4/1	Momentum representations, wavepackets (Ch 6.1 – 6.2).
12	4/12 – 4/14	Harmonic oscillator (Ch 9.1 – 9.4).
13	4/19	Harmonic oscillator (Ch 9.4 – 9.5).
13	4/21	**Exam II**.
14	4/26 – 4/28	Central potential, angular momentum (Ch 7.1 – 7.3).
15	5/3 – 5/5	Angular momentum, hydrogen atom (Ch 7.4 –7.6, 8.1 – 8.5).
16	5/10 – 5/12	Hydrogen atom, paradoxes (Ch 8.5, Ch 4).