Physics 430IA Quantum Mechanics Spring 2011

Meeting Times: MWF 10:00 - 10:50
Classroom: SCI 361
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Office Hours:

Day	**Times**
Tuesday	1-3 PM
Wednesday	1-4 PM
Thursday	1-3 PM
Friday	1-4 AM

Catalog Description An introduction to the techniques of quantum mechanics including the Schrödinger equation, eigenvalues and eigenstates, operators, matrix mechanics, and elementary perturbation theory. Simple systems such as barrier potentials, the harmonic oscillator and the hydrogen atom will be examined. Philosophical aspects of quantum mechanics will be discussed whenever possible. *PR: PHY 307I, PHY 320.*

What This Course is REALLY About This course is designed to introduce you to the fundamentals of quantum mechanics. The focus of this course is on the mathematical formalism of quantum mechanics. If you continue your study of quantum mechanics (in graduate school) then you will see how these basic techniques can be applied to real physical systems of greater complexity, but with the exception of the Hydrogen atom we will deal almost exclusively with simple model systems that illustrate the fundamental principles and techniques of quantum theory. Throughout this course we will focus of the wavefunction representation of quantum mechanics, although Dirac's more sophisticated notation will be introduced. A list of specific topics to be covered is given in the Course Schedule. In addition to traditional calculation problems, you will also be asked to do some supplemental reading and writing assignments that are intended to strengthen your conceptual knowledge of quantum mechanics. These supplemental assignments will emphasize that quantum theory has been developed to be consistent with *experimental* evidence.

How I Will Teach I believe that students learn best by doing things themselves, or with their fellow students. Most of our class time will be spent working through tutorial activities. You and a partner will work through important quantum mechanical derivations and calculations. This is a much more effective way for you to learn that material than listening to me lecture. That said, quantum mechanics is a difficult subject and there will be a few times when I will lecture in order to provide you with some assistance before you begin working through things on your own. Occasionally we will also use computer simulations to explore certain features of quantum mechanical system. In addition, you will be asked to read, write, and solve problems outside of class time. This course requires a lot of work on your part, but there is simply no other way to learn quantum mechanics. Don't feel bad - it requires a lot of work for me too!

What You Will Read The following books are *required* for this course:

- *Introduction to Quantum Mechanics* (2nd Ed.) by David J. Griffiths
- *Where Does the Weirdness Go?* by David Lindley
- various supplemental handouts on important quantum mechanical experiments

Why You (Should) Want to Take This Course After taking this course you should be reasonably well-prepared for a graduate course in quantum mechanics. You should also have a strong enough grasp of quantum mechanical concepts so that you can comprehend articles about quantum mechanical research in popular journals (like *Scientific American*, *American Scientist*, or *Physics Today*). This course will also expose you to a number of mathematical techniques that may be useful to you in other courses or in your future work. Even if you have no interest in pursuing further study in physics, this course provides you with an opportunity to learn about one of the most important theories in physical science.

Cool Stuff You Will Do By the End of This Course If you successfully complete this course you will do lots of very cool things. Here are a few of them:

- You will make (probabilistic) predictions about the outcomes of different kinds of measurements made on quantum systems.
- You will solve for the energy eigenstates and eigenvalues of simple 1D quantum systems.
- You will construct solutions to the Schr´odinger equation for a given initial condition in certain systems.
- You will read and write about some amazing experiments that illustrate the bizarre behavior of the quantum world.
- You will determine how the energy eigenvalues and eigenstates of a quantum system are affected by a small perturbation in the potential of the system.
- And more!

What You Can Do to Learn In this course there are many ways for you to learn, including:

- reading the assigned sections of your textbooks and supplemental readings,
- working through in-class tutorials,
- paying close attention to classroom lectures and computer demonstrations,
- completing all assigned homework,
- writing assignments (papers and Online Reading Quizzes), and
- discussions with the instructor outside of class.

What I Expect From You I expect everyone to learn a lot of quantum mechanics and to have fun doing it. In order to learn and have fun, here's what you need to do:

- Attend each class meeting and arrive on time.
- Complete all in-class tutorials to the best of your ability.
- Turn in all homework assignments on the day they are due (by 5PM). Late homework may be turned in at the next class meeting, but the score will be reduced by 50 %. After that no homework will be accepted.
- Complete all writing assignments on time. No late writing assignments will be accepted. If you are unable to complete a writing assignment on time you should discuss it with me.
- Read the relevant sections of the Griffiths text **before** they are discussed in class. This will make the tutorials go more smoothly, make lectures much more meaningful, and provide you with an opportunity to ask questions on things that were not clear in the text.
- Read the relevant pages of the Lindley book or supplemental handout **before** beginning the corresponding writing assignment.
- Come talk to me outside of class if you are having trouble with anything.

How I Will Determine Your Grade Your grade will be based upon the following criteria, weighted as indicated:

Tests 45 % (4 weighted equally)

Long Paper 15 %

Short Papers 10 % (2 @ 5 % each)

Homework 25 % ($\sim$ 45 problems, equally weighted)

Online Essay Questions 5 % (7 questions, equally weighted)

I may adjust the final grades (upward) at the end of the semester, but otherwise you should expect that you will receive an "A" for a grade in the range 90-100, a "B" for a grade in the range 80-89, etc. I will determine pluses and minuses at the end of the semester by examining the distribution of grades and taking into account my perception of the effort you have put into the course. **Your test average must be at least 50% in order for you to receive a passing grade in this course.**

Tests Tests will be take-home exams. You will have 3-5 days to complete each exam (but there may be time restrictions within that 3-5 days). You will be allowed to use your textbook and notes on any test. You may also use a table of integrals or a calculus book (or even a computer mathematics program like Maxima) if you like. You may not use any other materials (and you are especially forbidden to use another student's work or notes). You may NOT receive help from anyone (except, possibly, Dr. T).

Long Paper Early in the semester (see schedule) each student will be required to write a long (~ 5 pages) paper on the Stern-Gerlach experiment. This experiment is discussed in the Lindley book, but each student will also be required to carry out a series of simulated experiments using the SPINS interactive Java applet. Details will be provided in a separate handout. In addition, each student will be asked to write a peer evaluation of another student's paper. Finally, each student will be asked to re-write their paper and incorporate the suggestions/criticisms of the peer evaluators and the instructor. Each student's grade on this assignment will be determined by three factors: the overall quality of the paper after it has been rewritten, the quality of the student's evaluation of their peer's paper, and the extent to which the re-write of their paper addressed the comments and criticisms of their evaluators.

Short Papers Two short ($\sim 2-3$ pages) papers will be assigned during the semester. These papers will be responses to essay questions dealing with the material in the Lindley book as well as supplementary readings or activities. Details about each paper will be provided in handouts given later in the course.

Homework You will complete many homework problems from the Griffiths text. Feel free to work with other students in the class on these problems, but the work you turn in must be your own. This means that another student can explain the solution to you (or vice versa) but you cannot copy another student's written work or allow another student to copy your written work. You are also encouraged to seek assistance from me on homework problems. Each homework problem you turn in will be assigned a numerical score, based on the criteria given below. Your homework score will be the number of points you earn as a percentage of the maximum possible number of points that could be earned.

- **4** Solution is correct, complete, and clearly written. Solutions with minor errors may still receive this score. The solution indicates genuine effort and a strong understanding of the material.
- **3** Solution is complete but contains significant errors.
- **2** Solution is incomplete, but at least partially correct, or complete but totally incorrect.
- **1** Solution is incomplete and incorrect.
- **0** No solution was turned in.

Online Essay Questions Periodically you will answer an online essay question (due dates are indicated on the Schedule below). You will complete the essay questions using VikingWeb. Your response to each question should be a single paragraph (two, if you just can't help yourself). Most of the questions will be about material you have read in the Lindley book, but some may be about conceptual issues discussed in class or in the Griffiths text. You may be asked to visit some webpages to see interactive demonstrations of some quantum mechanical phenomena and comment on what you see. In this case the link will be provided within the online essay question. We will use the Forums feature in the Collaboration section of the VikingWeb page for this course. I will post the question as the first post of the forum. You should post your response. You will receive 2 points for an answer that indicates that you have read the relevant material and put some thought into the question. You will receive 1 point for an answer that indicates little preparation or thought. And, of course, you will receive 0 points for no answer. Although all answers will be public (in that you can read everyone else's answer and they can read yours) you should not, of course, copy from anyone else. Give your own answer to each question. I will post a response after the deadline for each essay has passed.

Americans with Disabilities Act Students with disabilities who believe that they may need accommodations in this class are encouraged to contact the Academic Support Center in Krannert 326 (Ext. 4080) as soon as possible to ensure that such accommodations are implemented in a timely fashion. No student will receive special accommodations without approval from the Academic Support Center.

Academic Integrity All work that you turn in must be your own. You may discuss homework problems with other students, but you may not copy their work or allow them to copy yours. You must complete all other assignments on your own with no assistance from anyone except me. If you are found in violation of Berry's policies on academic integrity (see the Viking Code) I will impose strict penalties (I may give you an automatic "F" for the course).

Additional References You may find some of these books helpful during this course, or you may be interested in reading more about quantum mechanics after you have completed this course.

- *Quantum Mechanics* (2nd Ed.) by Amit Goswami: A text I have used before.
- *Quantum Physics* (3rd Ed.) by Stephen Gasiorowicz: A brief but good text.
- *In Search of Schrödinger's Cat* by John Gribbin: A popular book about QM.
- *Alice in Quantumland* by Robert Gilmore: An allegorical tale of QM.
- *The Quantum Challenge* by George Greenstein and Arthur Zajonc: A popular book that focuses on experiments. I would have used *The Quantum Challenge* for this course instead of the Lindley book, but it is about $40 more expensive.
- *The Odd Quantum* by Sam Treiman: A semi-technical popular book that falls somewhere between other popular books and textbooks.

Course Schedule A tentative schedule of topics for the course is given below. I reserve the right to make any changes to this schedule that I feel are necessary.

Date	Text	Topic	Lindley	Due
12-Jan				
14-Jan	1.1-1.2	Schrodinger Equation		
19-Jan	1.3-1.4	Probability		
21-Jan	1.5-1.6	Momentum, Uncertainty	ix-8	1.1,1.3
24-Jan	2.1	Stationary States	8-26	OEQ 1
26-Jan	2.2	Infinite Square Well		start Long Paper
28-Jan		Properties of Bound States		1.5,1.7,1.9,2.1
31-Jan	2.3	Harmonic Oscillator I		
2-Feb	2.3	Harmonic Oscillator II		2.4,2.5,2.7,2.38
4-Feb	2.3	Harmonic Oscillator III		
7-Feb	2.4	Free Particle I		Long Paper draft
9-Feb	2.4	Free Particle II		2.10,2.11,2.12,2.13
11-Feb	2.4	Free Particle III	26-38	peer evaluations
14-Feb	2.5	Delta Well		OEQ 2
16-Feb	2.6	Finite Square Well I	29-52	2.21,2.22,2.23,2.27
18-Feb	2.6	Finite Square Well II	52-72	Long Paper rewrite
21-Feb	2.6	Scattering I	72-83	OEQ 3
23-Feb	2.6	Scattering II		OEQ 4
25-Feb	3.1	Hilbert Space		2.29,2.34
28-Feb	3.2	Observables and Operators		
2-Mar	3.3	Hermitian Operators		Test 1
4-Mar	3.4	Statistial Interpretation	155-177	3.1,3.2,3.3,3.5
7-Mar	3.5	Uncertainty Principle		OEQ 5
9-Mar	3.6			
11-Mar	4.1	Dirac Notation		3.7,3.13,3.17
21-Mar	4.1	Spherical Coordinates I		Short Paper 1
23-Mar	4.2	Spherical Coordinates II		3.22,3.23,3.31
25-Mar	4.2	Hydrogen Atom I		
28-Mar	4.3	Hydrogen Atom II		Test 2
30-Mar	4.3	Angular Momentum I	177-190	4.1,4.2,4.3
1-Apr	4.4	Angular Momentum II		4.10,4.11,4.13,4.16
4-Apr	4.4	Spin I	190-226	OEQ 6
6-Apr	4.4	Spin II		4.19,4.23
8-Apr	4.4	Spin III		OEQ 7
11-Apr	5.1	Addition of Angular Momentum		4.27,4.28,4.29
13-Apr	5.1	Identical Particles		4.34, 4.36, 4.51
15-Apr	6.1	Exchange "Forces"		
18-Apr	6.1	Perturbation Theory I		Test 3
20-Apr	6.2	Perturbation Theory II		
25-Apr	6.2	Degeneracies I		6.1,6.2,6.4
27-Apr	6.3	Degeneracies II		Short Paper 2
29-Apr	6.3	Fine Structure		6.8,6.9, 6.14
3-May		Final Exam Date		Test 4