Quantum Mechanics - II
PHYS 4308

Spring 2010, Tue-Thu 9:30 - 10:50 AM, SC039

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Office Hours: Tue-Thu 11:00-12:00 PM or by appointment, SC039.

Course Textbook: David J. Griffiths, *Introduction to Quantum Mechanics*, 2nd edition, Pearson - Prentice Hall, 2005. We will use this book as our main text. I will assign reading and problem assignments from this book. It is a good idea to own this book.

Supplementary Reference Textbooks: There are several good textbooks available in quantum mechanics. I list some of my personal preferences and I encourage you to study from any textbook that you feel is helpful.

1. These are considered undergraduate text books.
   (a) John S. Townsend, *A Modern Approach to Quantum Mechanics*, University Science Books, 2000.
   (b) Eugene Merzbacher, *Quantum Mechanics*.
   (c) A. F. J. Levi, *Applied Quantum Mechanics*, 2nd Edition, Cambridge University Press, 2006.
   (d) David A. B. Miller, *Quantum Mechanics for Scientists and Engineers*, Cambridge University Press, 2008.
   (e) Stephen Gasiorowicz *Quantum Physics*, 3rd Edition, John Wiley and Sons, 2003.
2. You will find the following useful for mathematical techniques that are widely used in physics.
   (a) Boas, M. *Mathematical Methods in the Physical Sciences*, 3rd edition, Wiley.
   (b) Arfken, G. *Mathematical Methods for Physicists*, 3rd edition, Academic Press, 1985.
   (c) Boyce, E. B. and DiPrima, R. C., *Elementary Differential Equations and Boundary Value Problems*, John Wiley and Sons, Inc., 1969.
   (d) Morse, P. M. and Feshbach, H., *Methods of Theoretical Physics*, McGraw-Hill Book Company, Inc., 1953.
   (e) Gradshteyn, I. S. and Ryzhik, I. M. *Table of Integrals, Series, and Products*, 5th edition, Academic Press, 1994.
   (f) Abramowitz, M. and Stegun, I. A. *Handbook of Mathematical Functions*, Dover Publications, Inc., 1972.

The objective of this course is to build on what was learned in PHYS4307 (Quantum Mechanics I) by moving onto advanced techniques and exploring modern concepts. We start with a very short review of PHYS4307 and concentrate on the principles of time-independent perturbation theory. The variational techniques are common and powerful tools in quantum mechanics and will be studied next. The WKB approximation will be followed by time-dependent perturbation theory where we will cover two-level systems, emission

and absorption of radiation, spontaneous emission and related phenomena. We will also discuss scattering theory both at low and high energy regimes. In addition to the more traditional advanced topics in quantum mechanics, we will spend time learning more recent concepts (EPR paradox and Bell's theorem, no-cloning theorem, von Neumann measurement, Zeno paradox, classical and quantum information, quantum computing, cryptology, quantum factoring, *etc*).

Requirements:

1. **Homework:** Homework sets will be assigned regularly and will be based on the material presented in class. Homework assignments will collected. There will be 6 sets. You are welcome to discuss the questions with me and/or your classmates.

2. **Attendance:** I expect all will attend class and participate in discussions. I also expect that you will occasionally present new material to class. If you have an excuse for not coming to class, call or send me an e-mail.

3. **Exams and Final Grade:** There will be one in-class closed-book and a final in-class exam. The final grade consists of 25% homework, 25% mid-term exam, 25% project, and 25% final exam grades. The final grading metric is 100-85:A, 85-70:B, 70-55:C, 55-40:D and 40-0:F.

Expected Learning Outcomes:

1. The student will understand and be able to solve quantitative problems involving hydrogen atom, helium atom, line splitting, tunnelling, emission and absorption of radiation, *etc.*

2. The student will be able to use advanced mathematical tools (perturbation theory and variational techniques) to express physical ideas in quantum mechanics.

3. The student will draw on all his/her knowledge to be able to creatively approach a new problem/project assigned at the end of the semester.

Assessment of Learning Outcomes:

1. The student will be observed in problem-solving sessions and in-class discussions and will be evaluated how he/she approaches and solves problems in exams and on the board. The student will be asked to explain to his/her peers ideas and solutions.

2. As above, the student will be evaluated in understanding of physical concepts as well as proficiency in mathematical tools.

3. The student will be evaluated on the class project which will include newly-acquired ideas in advanced quantum mechanics and mathematical sophistication.

Disability: Any student who, because of a disabling condition, may require some special arrangements in order to meet the course requirements, should contact the instructor as soon as possible, so that the necessary accommodations can be made. Proper documentation must be presented from the Dean of Students' Office.

PHYS 4308 Class Schedule

Week	Topic	M	T	W	Th	F
0	Time-independent Perturbation Theory Ch6		1/12		1/14	
1	Time-independent Perturbation Theory Ch6		1/19		1/21	
2	Time-independent Perturbation Theory Ch6		1/26		1/28 H1	
3	Variational Principle Ch7		2/2		2/4	
4	Variational Principle Ch7		2/9		2/11 H2	
5	Variational Principle Ch7		2/16		2/18	
6	The WKB Approximation Ch8		2/23		2/25 H3	
7	The WKB Approximation Ch8		3/2		3/4	
8	The WKB Approximation Ch8		3/9		3/11 **E**	
9	Spring Break		3/16		3/18	
10	Selected Topics		3/23		3/25	
11	Selected Topics		3/30		4/1 H4	
12	Selected Topics		4/6		4/8	
13	The Adiabatic Approximation Ch10		4/13		4/15 H5	
14	Scattering Ch11		4/20		4/22	
15	Scattering Ch11		4/27		4/29 H6	
16	Scattering Ch11		5/4			
			Last Day			

The chapters correspond to Griffiths' book. Occasionally, I will deviate from this schedule to cover material that complements Griffiths' sequence. HW assignment (H_n) where $n = 1, .., 6$. **E** means mid-term.

PHYS 4308 Project Topics (examples)

I list a set of topics that are related to what we will study this semester. The intention is to extend the ideas discussed in the course to other modern concepts. I would like you to go through this list and think about what you would like to do. You need to decide by the due date. Your task is to learn and report (a written paper and an oral presentation) on these ideas. In all cases, I include references from which you can start.

1. *Aharanov-Bohm Effect:* This is one of the interesting properties of the electromagnetic potentials in the quantum domain. Contrary to the conclusions of classical mechanics, there exist effects of potentials on charged particles, even in the region where all the fields vanish.

   - Y. Aharanov and D. Bohm, Phys. Rev. Lett. **115** (Aug 1959) 485.

2. *Berry's Phase:* Berry's phase is a topological phase that exhibits itself in many systems and one of which is in optical fibers, so-called anholonomy of coiled light. This geometrical phase shift in adiabatically transported quantum systems is a fact of nature and can be described at the level of classical electrodynamics.

   - M. V. Berry, Nature, **326**, 19 March 1987, p 277.
   - A. Tomita and R. Chiao, Phys. Rev. Lett, **57**, 1986, p 937.