Physics 216. Quantum Mechanics. Professor Dine

Spring, 2004. Syllabus

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Office hours: Monday 1:00-3:00 or by appointment.

Course website: go to department website and click on Dine, or go to http : //scipp.ucsc.edu/d̃ine Homework and solutions and handouts will be posted here.

Course Description: Last quarter, in Physics 215, you learned the basic formalism of quantum mechanics and solved some simple problems. You also mastered the theory of angular momentum, and solved problems such as the hydrogen atom, with spherical symmetry. This quarter, our goal is to develop some feeling about how to use quantum mechanics in the "real world." In particular, you have already encountered almost all of the systems for which the Schrodinger equation can be solved exactly, and we need to develop approximation methods. As we will see, not only do these approximation methods give us tools to solve interesting problems, but they also give us a way of comprehending many phenomena. The most important of these methods, for time-independent problems (solutions of the stationary Schrodinger equation) is perturbation theory, but we will also encounter others, including the variational method (perhaps reviewed briefly; I understand you covered this extensively in 215) and the WKB approximation. We will apply these methods to understanding the periodic table. Our study of the WKB method will also permit us to introduce the Feynman path integral. For time-dependent problems, time-dependent perturbation theory is the most useful approximation setup, but we will also consider the adiabatic and sudden approximations. We will apply time-dependent perturbation theory, during this course, to the problem of emission and absorption of radiation and also to scattering problems. The adiabatic approximation will find application in the study of molecules. The remainder of the course will be devoted to scattering theory and second quantization. Scattering is one of the most important tools physicists have, and understanding the connection between scattering measurements and underlying physics is of great importance. Second quantization allows the treatment of systems in which the number of particles is not conserved. One obvious example is electromagnetism, where the number of photons is not conserved, but the same ideas find application in condensed matter systems (e.g. phonons). Indeed, the methods of second quantization prove quite useful even for systems with conserved numbers of particles. They are particularly efficient for keeping track of particle statistics. If we are able to keep to our schedule, we will also devote two lectures to the Dirac equation.

Note on the texts: The principle text for the course will be Shankar's "Quantum Mechanics," but I will also borrow a great deal from Sakurai. Shankar is easy to read, and gives all of the essential material. But it is short on interesting examples, and doesn't always give you the most powerful tools. Sakurai is more sophisticated, though sometimes a bit terse. My lectures will not always follow the texts too closely, and I will give supplements from other books from time to time. Generally, you should do well, however, if you master Shankar's presentation. There are many things I have not included, but which you will probably want to read. These include: material from first quarter, presented somewhat differently than you are used to (chapter 1, early sections of chapter 2 on general formalism, meaning of quantum mechanics; section 2.5 on path integral, 2.6 on Bohm-Aharanov effect, 3.4 on density matrix, quantum statistical mechanics, 3.9 on Bell's inequality. You might want to at least skim chapters 4 and 6, which discuss material which you have covered, at least to some extent, last quarter as well (discrete symmetries, lattice symmetries, identical particles).

Books on Reserve: I have put a number of books on reserve, and strongly recommend you look at them. . These include

1. Messiah, *Quantum Mechanics.*
2. Davydov, *Quantum Mechanics.*
3. Schiff. *Quantum Mechanics.*
4. Sakurai, *Modern Quantum Mechanics*
5. *Feynman Lectures*, Volume III.
6. Cohen-Tanoujdi, *Quantum Mechanics*
7. Baym, *Quantum Mechanics*
8. Taylor, *Scattering Theory*
9. Merzbacher, *Quantum Mechanics.*
10. Landau and Lifschitz, *Quantum Mechanics.*

I will take supplementary materials for lectures and readings from several of these (see the syllabus below). Don't be embarassed about reading Feynman. He provides a great deal of insight. Schiff is somewhat old fashioned, but has good discussions of atomic physics, molecular physics and other applications. Messiah is rather formal, but treats a number of problems rather nicely. For example, I will probably provide a handout from this text with a treatment of scattering in terms of wave packets. Cohen-Tanoujdi has more physical examples than your texts. Baym has an excellent treatment of many topics, including second quantization (which we will use).
I will put other books on reserve from time to time as seems appropriate.

Homework, exams,etc: There will be a problem set about every 10 days, and an in-class final. Because I know the final last quarter caused some difficulty, there will be a midterm. The subject matter is not really that difficult, but it is essential to review class notes and to keep up in the reading and the homework. I will miss at least one lecture during the quarter (April 6). I appreciate your indulgence in scheduling makeup lectures.

Tentative Schedule

- March 30, April 1. Time-Independent Perturbation Theory (non-degenerate and degenerate cases) (Shankar 17, Sakurai 5.1-5.3).
- April 6 **makeup to be scheduled**. The periodic table: getting to apply everything you know so far. Handout from Schiff.
- April 8,13. The WKB approximation, tunneling, perhaps a little bit of path integration. (Shankar 16, Sakurai 5.4, also pp. 104-109 from chapter 2. Supplementary handouts).

- April 15, 20, 22. Time-dependent problems: Adiabatic and Sudden Approximations, Time-Dependent Perturbation Theory (Shankar 18, Sakurai 5.5-5.7). Molecules as an application of the adiabatic approximation (supplementary handout, probably from Schiff).
- April 27, 29, May 4. Emission and absorption of radiation. Second quantization of the radiation field. (Shankar, 18, and supplementary materials).
- May 6,11,13. Scattering Theory (Shankar 19, Sakurai, 7).
- May 18, 20. Second quantization (handout from Baym).
- May 25, June 3. Dirac equation (Shankar, chapter 20).