

University of Maryland
Department of Physics, College Park, MD 20742

Physics 401----Quantum Physics I----Fall 2004

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Office Hours

Office hours are immediately following class. I am also generally available in my office and happy to see students; just drop by--or, better yet, give me a call and then drop by.

Course Philosophy

In my opinion quantum mechanics is, without a doubt, the most intellectually beautiful part of the undergraduate physics curriculum and indeed one of the most beautiful in all of physics. It is a very rich subject in terms of both the phenomena it describes and in its formal development. The course will start by describing a few phenomena that simply cannot be understood in terms of the classical physics of Newton and Maxwell. Examples of such phenomena are the photoelectric effect, the Compton effect and atomic spectroscopy.

During the first quarter of the 20th century quantum ideas were developed to describe such effects and we will explore these ideas including some of the rather bizarre philosophical implications. Quantum physics at that stage was not part of a fully systematic and consistent framework. Starting in 1925 such a framework---quantum mechanics---was rapidly developed by Schrödinger, Heisenberg, Dirac and others.

Indeed, initially it seemed that there were *two* such frameworks: the wave mechanics of Schrödinger, and the matrix mechanics of Heisenberg. However, Dirac soon developed a general treatment using abstract vector spaces and was able to show that Schrödinger's wave mechanics and Heisenberg's matrix mechanics were mathematically equivalent and were both special cases of the general formulation.

The course will begin with a historical survey of some of the outstanding problems in physics at the end of the 19th century which lead to the development of quantum mechanics. Next, quantum mechanics will be introduced in the framework of Schrödinger's wave mechanics since the principal mathematical tool of this approach---a wave equation--- is more familiar to most students. We will use this approach initially to study one simple problem, the one dimensional infinite square well. We will concentrate initially on understanding the basic formalism and its implications (such as the Heisenberg uncertainty relation). Having built up some intuition about quantum mechanics from this example, we will return to the formalism and develop Dirac's approach in terms of abstract vector spaces. Then we will turn our attention to a number of simple applications in one dimension. Additional physically interesting applications of quantum mechanics will be treated in Physics 402. If time permits we will return to the formal structure of the theory.

Books

The principal text for the course is Liboff's *Introductory Quantum Mechanics*. The book is very readable and clear. It has a couple of drawbacks for the purposes of this course. The principal drawback is also its principal strength. It develops an abstract formalism for quantum mechanics relatively early. Thus, there is a lot of mathematical heavy lifting early in the course. Having mastered this however, the remainder is straightforward.

Homework

Problem sets will be assigned regularly. Problem sets may require the use of numerical analysis that can be done in *Mathematica* or some other computer program. I strongly encourage students to consult each other on problem sets. Ideally you should attempt all of the problems by yourselves and if you get stuck you should then consult your peers. Homework will count approximately 20% of the final grade.

Not all problems will be graded---a representative sample will be. A set of solutions to the homework problems prepared by the TA will be posted on the course web site for additional feedback. These solution sets may in part consist of corrected solutions submitted by students in the course.

Exams

There will be a midterm exam and a final exam in this course. The exams will count for approximately 80% of the total course grade.

The exams are currently planned as take-home. Take-home exams have two virtues: they reduce the time pressure on students and allow them to perform at their best and they allow for questions that are less trivial than can be done during a class period. They

do have a potential drawback, however. They are impossible to police efficiently against cheating. Thus, we must rely on your integrity. I will ask you to pledge to do the exams alone and to stick to this pledge. I should note that the whole enterprise of science depends on the integrity of the researchers--- when I read a scientific paper I must assume that the researchers didn't cook the books or I won't get anywhere.

Tentative Course Outline

Introduction to Quantum Phenomena (Chapter 2)

- Black-body radiation and Planck's conjecture
- Einstein's explanation of the photoelectric effect; photons;
- Wave-particle duality for light---Compton scattering.
- The Bohr atom; connection of quantum phenomena to atomic spectroscopy
- De Broglie's hypothesis; wave-particle duality for matter.
- Interference and the Davisson-Germer experiment.
- Born's probability interpretation of the wave function; Resolution of particle/wave duality.
- Motivating the Schrödinger equation; momentum as a differential operator

Introduction to the Schrödinger Equation

- Formal treatment of probability; normalization of the wave function
- Local conservation of probability
- Momentum in the Schrödinger equation; non-commuting operators
- Time-dependent vs. time-independent Schrödinger equations; stationary states and their superpositions
- The infinite square well (Chap 4.1,4.2, 5.1)

The formalism of Quantum Mechanics

- Postulates of Quantum Mechanics---operators, measurements and time evolution (Chap 3)
- Hermitian operators and physical observables (chap 4)
- Dirac Notation (chap 4)
- Commutators and Uncertainty (Chap 5)
- Time evolution and conservation laws (Chap 6)

Quantum Mechanics in One Dimension

- Harmonic oscillator; creation and annihilation operators (Chap 7)
- Free particles; propagation (Chap 7)

- Tunneling Scattering and resonance (Chap 7)
- Finite Well (Chap 8)
- Semi-Classical limit (Chap 7)

More Formal Issues

- More on the Dirac Approach
- Matrix Formulation (Chap 11)