PHYSICS 438A Quantum Mechanics

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Textbook: *Introduction to Quantum Mechanics*
David J. Griffiths, 2nd edition

Prerequisite: Physics 304, Mechanics
Corequisite: Math 445, Mathematics of Physics & Engineering II

The course "*Introduction to Quantum Mechanics*" follows the Mechanics class. However, it opens the door to a completely different world. We don't notice quantum phenomena in our daily experience, but the working of quantum theory underlies everything. The light that we see is quantized, and the Planck constant times the frequency gives the smallest energy quantum of the electromagnetic radiation. Besides the individual atoms, the structure of molecules is dominated by QT. Even the proteins in our body use quantum phenomena in their functions. The properties of solids are determined by QT, for example whether a piece of matter is a metal or an insulator. Even the distribution of matter in the universe is most likely the result of quantum fluctuations in the very early phase of the big bang. Although QT has been already known for more than a century, there are still important open questions. So far one has not been able to merge QT with gravity. At the horizon of a black hole our understanding is limited and the laws of physics for the center of a black hole still have to be discovered. So there are great challenges waiting for solutions.

This course will introduce the concept of QT. While in Mechanics the main task is to calculate the dynamic of a system (a force accelerates a mass), in QT one initially considers systems in equilibrium. Here the first task is to calculate the energy states of a system. Examples are a mass on a spring, the so-called harmonic oscillator, or an electron in the potential of a proton. Then operators are introduced which permit to (theoretically) measure the properties of the system. The calculation of transition probabilities is a first step into the dynamics of a system. Experimental measurement in a system – for example the measurement of the position of a mass – yields the Heisenberg uncertainty principle, which says that for example both the position and momentum of small mass (for example an electron) cannot be determined with arbitrary accuracy.

But one of the most amazing consequences of QT that a particle can be at different places at the same time, an electron spin can be up and down at the same time. This property is at the heart of the proposed quantum computer where the quantum-bit (qubit) is in two states at the same time. A quantum computer with n qubits is in two to the power n states at the same time. It has therefore 2^n different amplitudes which is similar to having performed 2^n calculations at the same time yielding a much richer information. This area still offers a wide range of research in the theory as well as in the technical realization of a powerful quantum computer.

Schedule of the class

Week date		Material Covered
1 01/15		De Broglie Waves, 1.1 Schrödinger Equation 1.2 Statistical Interpretation, 1.3 Probability
2 01/22		1.4 Normalization, 1.5 Momentum, 2.1 Stationary States,
3 01/29		2.2 The Infinite Square Well
4 02/05		2.3 The Harmonic Oscillator, The Harmonic Oscillator
5 02/19		The Harmonic Oscillator 2.4 The Free Particle
6 02/26	x	I Midterm 2.5 The delta-function potential
7 03/05		3.1 Hilbert space, 3.2 Observables 3.3 Hermitian Operators
8 03/12		3.4 Statistical Interpretation 3.5 Uncertainty Principle
9 03/19		Spring Recess
10 03/26		3.6 Dirac Notation 4.1 Schrödinger equ. in Spherical Coordinates
11 04/02		4.2 The Hydrogen Atom The Hydrogen Atom
12 04/09	 x	The Hydrogen Atom II Midterm
13 04/16		4.3 Angular momentum Angular momentum
14 04/23		4.4 Spin Spin
15 04/30		Oddities of quantum theory, Review
05/06		Final

Material to be covered in the course from the textbook is the chapters:

1. The wave function
   - The Schrödinger equation
   - Statistical interpretation
   - Probability
   - Momentum
2. Time-independent Schrödinger equation
   - Stationary states
   - The infinite square well
   - The harmonic oscillator
   - The free particle
   - The delta-function potential
3. Formalism: Dirac notation & matrix methods.
   - Hilbert space
   - Observables
   - Hermitian operators
   - Uncertainty principle
   - Dirac notation
4. Quantum mechanics in three dimensions
   - Schrödinger equation in spherical coordinates
   - The hydrogen atom
   - Angular momentum
   - Spin