

PHY451 QUANTUM PHYSICS I

Spring 2003

Professor Griffin

Course Text: INTRODUCTION TO QUANTUM MECHANICS - David J. Griffiths

DISCUSSION OF COURSE

During the first quarter of this century, there was a revolution in physics resulting in the theory of relativity and quantum mechanics. Classical mechanics failed to explain experimental evidence arising from atomic physics, which led Planck, Bohr, Schrödinger, Heisenberg, Born, Dirac, and many others to the development of quantum theory. Classical mechanics is based on observations of macroscopic phenomena, and it should not be surprising that the laws of classical mechanics do not explain microscopic phenomena. Nevertheless, because of its dependence on observable macroscopic phenomena with which we are all familiar, classical mechanics has the advantage of being consistent with our intuition regarding our physical environment. Quantum mechanics forms the foundation of most of the physics of today; however, having developed from microscopic experimental evidence, it is much less intuitive. In this course, we will undertake an introduction to non-relativistic quantum theory. It requires a completely different way of thinking about our physical universe. At times you may find this new interpretation of physical phenomena somewhat confusing, albeit interesting. However, bear with it, and by the end of the term you too will begin to think "quantum mechanically."

We shall meet four times a week on Monday, Wednesday, Thursday, and Friday. **Attendance at all class meetings is required.** The course will be divided up into units, and I will provide a reading and problem assignment sheet for each unit. **It is extremely important that you read the assigned material before each class.** In some cases, I will be doing things differently and in more detail than you will find in the text. After you have completed the reading, the lecture and discussion sessions will be much more valuable to you and you will be ready to ask questions and participate in the discussions. For one class meeting within each unit, we will work together on problems assigned as GROUP problems. You can help each other with these, and I will be there to help you all when you get stuck. I will grade you on your effort to do the problems assigned as GROUP problems. There will also be FORMAL problems that you will be expected to **do on your own** and turn in.

COURSE EVALUATION

1. FORMAL PROBLEM SETS	22%
2. PRESENTATION OF GROUP PROBLEMS AND PARTICIPATION IN LECTURE DISCUSSION SESSIONS	12%
3. Tests (3 including final)	66%

COURSE OUTLINE

- I. The Wave Function
 - A. The Schrödinger Equation
 - B. The Statistical Interpretation of the Wave Function
 - C. Probability
 - 1. Discrete variables
 - 2. Continuous variables
 - D. Normalization of the Wave Function
 - 1. The total probability must equal one
 - 2. The continuity equation for probability and the probability current
 - E. Momentum in Quantum Mechanics
 - 1. Momentum as an operator in position space
 - 2. Ehrenfest's theorem
 - F. A Brief Introduction to the Uncertainty Principle

- II. The Time-Independent Schrödinger Equation In One Dimension
 - A. Stationary States
 - 1. When the potential is independent of time it separates
 - 2. The general solution of the time-independent Schrödinger equation
 - 3. Properties of stationary states
 - B. The Infinite Square Well
 - 1. Solution to the Schrödinger equation
 - 2. Properties of the solutions
 - 3. Solutions when the well is centered on the origin
 - C. The One-Dimensional Harmonic Oscillator
 - 1. The classical oscillator
 - 2. The direct solution of the Schrödinger equation
 - 3. Comparison of classical and quantum mechanical solution
 - 4. Solution using step-up and step-down operators
 - D. The Free Particle
 - 1. A brief review of Fourier integrals
 - 2. The wave function - problems with normalization
 - 3. The momentum wave function
 - 4. The wave packet
 - a. phase and group velocity and the spreading of the wave packet
 - b. the Gaussian wave packet
 - E. The Delta Function Potential
 - 1. A little bit about free and bound states
 - 2. The bound-state of the delta-function potential
 - 3. Scattering from a delta-function potential
 - a. nature of the reflected and transmitted waves
 - b. reflection and transmission coefficients

- F. The Finite Square Well
 - 1. The bound-states for the finite square well – analytical and numerical solutions
 - 2. Scattering from a finite square well
 - 3. Scattering from a square barrier
 - G. The Scattering Matrix
- III. The Formal Structure of Quantum Mechanics
- A. Linear Algebra
 - 1. Vector spaces
 - 2. Inner products
 - 3. Linear transformations
 - a. matrix representation
 - b. matrix properties
 - 4. Eigenvectors and eigenvalues
 - 5. Hermitian transformations
 - B. Function Spaces
 - 1. Functions and vectors
 - 2. Operators and linear transformations
 - 3. A little bit about Hilbert space
 - C. The Generalized Statistical Interpretation of Quantum Mechanics
 - 1. Hermitian operators and observables
 - 2. Discrete and continuous basis sets
 - 3. The momentum wave function revisited
 - D. The Uncertainty Principle
 - 1. The generalized uncertainty principle and commutators
 - 2. The rate of change of expectation values - conserved quantities in quantum mechanics
 - 3. The minimum-uncertainty wave packet
 - 4. Energy-time uncertainty
- IV. Quantum Mechanics in Three Dimensions
- A. The Three-Dimensional Schrödinger Equation
 - 1. The Schrödinger equation in three dimensions
 - 2. The gradient, divergence, and Laplacian operators in three-dimensional orthogonal vector spaces
 - 3. The Schrödinger equation in spherical coordinates
 - 4. Separation of variables
 - B. The Angular Equation
 - 1. Eigenvalues and eigenfunctions
 - 2. The spherical harmonics
 - D. The Radial Equation
 - 1. The effective potential
 - 2. The solution of the radial equation for the hydrogen atom
 - E. The Properties of Hydrogen
 - 1. The energy spectrum

2. Spatial distribution of the solution
 3. The parity of the solutions
- F. Angular Momentum
1. The angular momentum operator
 2. The commutation relationships for angular momentum
 3. The raising and lowering operators for angular momentum
 4. The eigenvalues and eigenfunctions of the angular momentum operators
- G. Spin
1. The properties of the spin operators
 2. Spin $\frac{1}{2}$ properties
 - a. eigenvalues and eigenvectors
 - b. the Pauli-spin matrices
 3. The electron in a magnetic field
 - a. Larmor precession
 - b. the Stern-Gerlach experiment
 4. The addition of two spins