Third Year Quantum Mechanics
Course Summary - First Semester 2008

Lecturer: Ian McArthur

Assessment: 20% based on performance in weekly assignments, 20% on the basis of a 40 minute mid semester test, and 60% on the basis of a two hour written examination during the first semester examination period.

Lecture Content

Lecture 1. Revision of wave mechanics - wave functions, Schrödinger equation and time evolution of wave functions, operators and measurement. Illustration of some general principles in the case of the infinite square-well potential: energy eigenfunctions as a complete orthonormal set, determining the probability distribution for outcomes of energy measurements

Lecture 2. Operators associated with observables as Hermitian operators: reality of eigenvalues, orthogonality of eigenfunctions, completeness of sets of eigenfunctions. Aside on Fourier integrals.

Lecture 3. The Dirac delta function. Momentum eigenfunctions and their properties

Lecture 4. Foundations of matrix mechanics: functions as vectors in a vector space, inner-product on the vector space, complete orthonormal sets of functions, Hermitian conjugation of operators.

Lecture 5. Dirac notation: association of a "ket" with a function, action of operators on kets, eigenkets of the momentum and position operators, "bras" as dual vectors, expression of the unit operator in bra-ket notation for a complete orthonomal set.

Lecture 6. Matrix mechanics expressed in Dirac formalism: association of a ket with a state, relation to the wavefunction, time evolution of the state vector (or ket).

Lecture 7. The simple harmonic oscillator revisited: wavefunctions for energy eigenfunctions, expression of the Hamiltonian in terms of raising and lowering operators, obtaining the energy eigenfunctions using ket notation.

Lecture 8. Spin angular momentum: no classical analogue, spin angular momentum operators, quantization of spin angular momentum

Lecture 9. Relationship between spin angular momentum and magnetic moment of a partice, Stern-Gerlach apparatus as a means to prepare spin one-half particles in particular spin states, use of the Stern-Gerlach apparatus to make measurements of the spin state, spin eigenstates associated with a particular axis.

Lecture 10. Spin one-half systems as a two-dimensional vector space, choices of bases. Representation of the spin operators in terms of the Pauli matrices.

Lecture 11. Commutation relations for the spin operators. Expression of arbitrary spin eigenstates in terms of a basis associated with the z-axis. Probability amplitudes for the measurement of spin along an arbitrary axis.

Lecture 12. Quantum measurement theory. Time development of a system expressed relative to an arbitrary basis of states. Matrix elements of the Hamiltonian.

Lecture 13. Magnetic moments of electrons and protons. Classical analysis of Larmor precession. Quantum treatment of Larmor precession.

Lecture 14. Symmetries as operations that preserve the time development of a system. Characterization of symmetry operators as operators that commute with the Hamiltonian. Symmetries and conserved quantities.

Lecture 15. Active and passive views of symmetry transformations. The translation operator. The momentum operator as the generator of spatial translations.

Lecture 16. The rotation operator. The angular momentum operator as the generator of rotations. The Hamiltonian as generator of time translations.

Lecture 17. Eigenfunctions of the angular momentum operators. Raising and lowering operators. Quantization of angular momentum

Lecture 18. Matrix representations of the angular momentum operators.

Lecture 19. Addition of angular momentum.

Lecture 20. Spin angular momentum operators as generators of rotations on spin degrees of freedom

Lecture 21. Physical significance of uncertainty relations, derivation of uncertainty relations.

Lecture 22. Time development of systems. Schr"odinger picture in which time dependence resides in states. Expectation values of operators. Heisenberg picture in which time development resides in operators. Heisenberg equations of motion for Heisenberg operators. Comparison with classical mechanics.

Lecture 23. Perturbation theory

Lecture 24. (not examinable) Treatment of the spin-orbit interaction in the hydrogen atom using perturbation theory.