Physics 562, Quantum Mechanics II
Syllabus of Spring 2008

Instructor:

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Time and Location:

10:10 am-11:00 pm, Monday, Wednesday and Friday
116 Osmond.

Office hours:

Any time

Pre-requisite:

Physics 561, Quantum Mechanics I

Text Book:

There is no text book on this advanced book

Reference Books put on reserve in the library:

J.J. Sakurai , Modern Quantum Mechanics, (Revised edition)
Cohen-Tannoudji, et.al , Quantum Mechanics, Vol. I and II (1977)
D. F. Walls and G.J. Milburn, Quantum Optics

Grading information:

There will be 2 exams and 6 home work sets:
(1) Exam 1, 30 %
(2) Exam 2, 40 %
(3) Homework: 5 % $\times$ 6= 30 %.
A letter grade will be given as your final grade

Tentative Syllabus:

Many basic concepts and applications of quantum mechanics were taught by Prof. Prof. Murat Gunaydin on quantum mechanics I (Phys561). In this advanced quantum mechanics course, in addition to presenting some traditional topics (70 to 80 %) such as coherent state, theory of angular momentum, time dependent perturbation theory, scattering theory, I will

also cover some topics (20 to 30 %) which are of current research interests in quantum optics, ultra-cold atomic experiments, quantum Hall effects, quantum computing and information theory.

1. **Coherent state, Squeezed state and their applications in quantum optics and quantum Hall effects:**

   (a) Coherent state in one dimensional harmonic oscillator

   (b) two dimensional harmonic oscillator and angular momentum

   (c) a charged particle moving in a uniform magnetic field and angular momentum, wave function in the lowest Landau level (LLL). Bergmann's Hilbert space of analytic functions.

   (d) Aharonov-Bohm effect, topology of the vacuum

   (e) Coherent and squeezed states of photons, Displacement operator, squeezing operator, detection of the squeezed state by phase sensitive homodyne measurements.

   (f) N identical fermion Wavefunctions in integer and fractional quantum Hall effects. quantization of Hall conductance, groundstate wavefunctions, quasi-hole wavefunctions, fractional charge, fractional statistics, edge states, edge-bulk correspondence, quantum Hall plateau-plateau transitions, topological order, Non-Abelian statistics, topological quantum computing.

2. **Scattering theory, bound state and resonance.**

   (a) Green functions, scattering amplitude, Lippmann-Schwinger Equation, transition matrix, scattering cross section, Born approximations, form factor

   (b) Parity operator, non-conservation of parity in weak interaction, Time reversal symmetry operator, Karamer's degeneracy, the symmetry of transition amplitude under parity, time-reversal and rotation

   (c) Partial wave method, plane wave versus spherical waves with all angular momenta, phase shift, Optical theorem, absorption in a complex potential

   (d) Calculation of phase shift. Scattering in (1) hard sphere, low energy and high energy limit (2) Square well potential, bound state, scattering state (3) Delta-shell potential, bound state, scattering state (4) Non-local separable potential, bound state, scattering state

(e) Low energy scattering and zero energy bound state, unitary limit, divergence of scattering length.

(f) Quasi-bound state with positive energy and finite life-time, resonance scattering with Lorentzian shape, Breit-Wigner formula.

(g) Identical particle scattering: (1) two identical spinless bosons scattering, (2) unpolarized and polarized two spin-1/2 fermions scattering.

(h) Feshbach resonance in recent ultra-cold degenerate Fermi gas experiments. S-Wave BEC to BCS crossover.

3. **Theory of Angular momentum**

   (a) Addition of two angular momenta, Clebsch-Gordan (CG) coefficients, addition of orbital angular momentum and spin, addition of two spins.

   (b) Vector operator, Spherical tensor operator, Wigner-Eckart Theorem, projection theorem, Lande factor.

4. Time dependent perturbation theory, transition probabilities, Fermi's golden rule, absorption, stimulated emission, spontaneous emission of lights.

5. Einstein-Podolsky-Rosen paradox, Bell in-equality, Schrodinger cats, spin correlation measurements, entanglement, quantum information