Physics 221A, Fall 2003
Course Outline

Instructor: Martin White, 561-C Campbell
GSI: Peter Shepard (pgs@socrates)
Lectures: M/W/F 9-10am, 102 Moffitt
Office Hours-MW: W 10-11 (561-C Campbell)
Office Hours-PS: M 11-12, F 1-2 (254 LeConte)
Section: T 4-5 (9 Evans), F 3-4 (71 Evans)
Exams: problem sets (30%), midterm (30%), final (40%)
Texts: Merzbacher (Sakurai, Baym, Liboff)

1. Fundamentals of Quantum Mechanics
   (a) Interference and uncertainty
   (b) Linear algebra, Hilbert spaces and bra-ket notation, connection with wave mechanics
   (c) Postulates of QM, precise statement of Uncertainty Principle
   (d) Polarized light and the density matrix
   (e) Entangled states, no-cloning theorem, EPR and Bell's inequalities
   (f) Quantum cryptography
   (g) Time evolution and the Schrödinger equation.
   (h) Schrödinger and Heisenberg pictures, spin precession and the non-classicality of the spin-vector
   (i) Connection with classical mechanics, Ehrenfest and virial theorems.
   (j) Path integral formulation.
   (k) Galilean invariance, wave packets and propagators
   (l) The Aharanov-Bohm effect
2. One-dimensional problems in Wave Mechanics
   (a) Connection of bra-ket notation with Wave Mechanics, stationary states
   (b) Conservation of probability current and speading of the wavepacket
   (c) Escape proof box, bound states, symmetry of states, double well
   (d) Scattering theory in 1D, phase shift, resonances and bound states, evolution of a wave packet
   (e) Periodic potentials, Bloch waves and energy bands, tight binding model, and conductors, scattering off defects
   (f) Nanocircuits and the Quantum Point Contact, Landauer conductance
   (g) Harmonic oscillator, raising and lowering operators, coherent states
   (h) Example of decoherence, Schrödinger's cat
3. Interlude – Quantum computing
   (a) Qubits, gates and complexity
   (b) Single qubit logic gates
   (c) Finding the period of a sequence
   (d) Shor's factoring algorithm
   (e) Grover's search algorithm
4. WKB Methods
   (a) The classical limit and semi-classical methods
   (b) Matching conditions and integral quantization condition
   (c) Quantum bouncing ball and evanescent waves
   (d) Barrier penetration
   (e) WKB and the virial theorem
5. Angular Momentum

(a) Group theory of rotations and angular momentum as generators

(b) Representations of the rotation group

(c) Vector addition coefficients

6. Many particles and many dimensions

(a) Many particle systems

(b) Systems of more than 1D

7. Hydrogen atom

(a) Central potentials

(b) Separation of variables

(c) Energy eigenvalues/eigenfunctions

(d) $O(4)$ symmetry

8. Time-independent perturbation theory

(a) Rayleigh-Schrödinger non-degenerate perturbation theory

(b) Harmonic oscillator with a linear perturbation

(c) Degenerate perturbation theory

(d) Fine structure, Hyperfine structure, Zeeman effect, Stark effect, Van der Waals force

(e) Rayleigh-Ritz variational method

(f) Brillouin-Wigner expansion

9. Time-dependent perturbation theory

(a) Interaction representation

(b) Transition rates

10. Scattering Theory

(a) 3D scattering theory

(b) Elastic 2-body scattering

(c) Lifetimes of states