MIT Subject 8.322 Quantum Theory II

R. L. Jaffe 2007

Syllabus

This is an **optimistic** syllabus. Material that may be omitted for lack of time is in blue.

I Relativistic Wave Equations

- A The problem: Lorentz covariance
- B The Klein-Gordon equation
- C Dirac's equation
  1. Derivation, Dirac matrices (chiral and Bjorken and Drell)
  2. Massless case: Weyl's equation
  3. Operators, angular momentum and spin
  4. Hamiltonian form and equations of motion
  5. Bispinor notation
- D Non-relativistic reduction of the Dirac equation and the g factor of the electron.
- E Lorentz covariance of Dirac's equation
  1. Meaning, example of KG equation
  2. Solution and interpretation
  3. Bilinear covariants.
  4. Generalizations
- F Single particle solutions of the Dirac equation
  1. Counting states, projection operators
  2. Momentum eigenstates and their high energy limit.
- G More applications of the Dirac equation if time permits.

II Approximation Methods

- A Stationary state perturbation theory
  1. Brillouin-Wigner perturbation theory
  2. Rayleigh-Schrödinger perturbation theory
  3. Degenerate perturbation theory
  4. Degeneracies past first order
  5. Convergence of perturbation theory
     A. A convergent example — radius of convergence
     B. Asymptotic expansions
  6. Examples:

A. Perturbations of the harmonic oscillator
B. Fine structure of hydrogenic atoms
C. Weak and strong field Zeeman effect in hydrogen

B Variational methods

1 Basic theorem
2 Practical considerations
3 Extensions to excited states, interlacing theorem, partial diagonalization.
4 Examples: Ground state of helium, bound states in open geometies

C Semiclassical methods

1 The WKB approximation, the classical limit and the Hamilton-Jacobi equation.
2 The need for connection formulae and their derivation
3 Interpretation of the connection formulae.
4 Applications: Bohr-Sommerfield quantization, quantum tunneling, etc.
5 Reflection above the barrier.

D Adiabatic approximation

1 Discussion and "derivation"
2 Transition rate in the adiabatic limit — relation to WKB
3 Born-Oppenheimer approximation
4 Berry's phase, theory, applications, relation to Hannay's angle.

III Many particle systems

A Indistinguishability and statistics
B Exchange symmetry, spin and statistics
C Two particle systems, exchange interaction, effective spin dependence, the classical limit and the significance of statistics.
D Permutation symmetry

1 Permutations
2 The totally symmetric and totally antisymmetric representations
3 Slater determinant
4 Representations of the permutation group
5 The representations of S_3.
6 Young diagrams and Young tableaux
7 States of three particles
8 The p-states of nitrogen