215B Quantum Mechanics II

Course description

Further development of quantum mechanics, focusing on symmetries, perturbation theory, and scattering. Proposed syllabus: identical particles, symmetries, angular momentum, hydrogen atom, variational methods (including some introduction to tensor networks), perturbation theory and scattering. Roughly corresponds to Chapters 10-19 from Shankar (2nd Ed).

Detailed syllabus

Symmetries: Continuous symmetries, rotations and spin algebra. Representations on spins and connection to spherical harmonics. (2 lectures)

Many-component systems: general overview of composite systems and symmetries of identical particle wavefunctions (1 lecture)

Hydrogen atom and beyond: solution of Coulomb potential in 3 dimensions and atomic spectra. (2 lectures) Optional: generalizations to other many-body problems, e.g., nuclear spectra and connections to random matrix theory (1 lecture)

Representation theory II: Spin and Clebsh-Gordon rules. Schur's Lemma, tensor products and decomposition into irreducible representations. Degeneracy breaking (eg., multi-dimensional oscillators). (2-3 lectures) Optional: Representation of Lie algebras (1-2 lectures)

Variational methods: Variational ansatz for wavefunctions. Relaxation methods. Modern approaches to variational wavefunctions: tensor networks (matrix product states) for lattice spin systems. WKB approach to spectra and wavefunctions, asymptotic properties of spectra. (3-4 lectures) Optional: complex saddle techniques and matched asymptotic methods (1-2 lectures)

Perturbation theory: Time independent perturbation theory recap. Secular term and degeneracies. Time dependent perturbation theory, interaction picture: general formalism and applications to matter-radiation interactions. (3-4 lectures)

Scattering theory: Basics of scattering theory (1d examples of refection/transmission). Lippmann-Schwinger, cross-sections, partial waves, Born and eikonal approximations and two-particle scattering examples. (3-4 lectures)

Resources:

J J Sakurai, Jim Napolitano Modern Quantum Mechanics (2nd ed).

Leslie Ballantine, Quantum Mechanics: A Modern Development

Steven Weinberg, Lectures on Quantum Mechanics

R Shankar, Principles of Quantum Mechanics (2nd Ed).

P A M Dirac, Principles of Quantum Mechanics