Special/Select Topics in Atomic Physics - Video course

COURSE OUTLINE

This course has evolved out of the following courses offered for M.Sc. (Physics) students at IITMadras:

1. Quantum Mechanics I
2. Quantum Mechanics II
3. Atomic and Molecular Physics
4. Atomic and Molecular Spectroscopy and
5. Theory of Atomic Collisions and Spectroscopy

The course will begin with the identification of a complete set of compatible observables for the non-relativistic Hydrogen atom, identify the complete set of 'good quantum numbers', discuss the associated constants of motion, and associated symmetries. The Laplace-Runge-Lenz vector and the Fock SO(4) symmetry of the Hydrogen atom will be discussed.

This will be followed by a discussion on coupling of Angular Momenta, Clebsch-Gordan Coefficients, Statement and Proof the Wigner-Eckart Theorem.

We shall then discuss the relativistic Hydrogen atom, Dirac equation. Foldy-Wouthuysen Transformation of Dirac Hamiltonian and Lamb shift.

Subsequently, the many-electron atom will be discussed to acquire an understanding of the Hartree-Fock Self-Consistent Field Formalism.

We shall then examine a Perturbative approach to relativistic effects; this would provide insight in the relativistic quantum mechanics discussed in an earlier unit based on the Dirac equation.

We shall then proceed to discuss methods to probe the atom. The methods are based on the alternative probes which use quantum collisions of atomic targets with probe particles and probing the atom with an electromagnetic field. We shall discuss the connections of these methods through the time-reversal symmetry and obtain the quantum solutions using appropriate boundary conditions. We shall obtain expressions for scattering cross sections, and also for photoionization cross-section and the angular distribution of the photoelectrons.

We shall then examine the quantum mechanics of atoms in external fields and study the Stark effect, and also the family of ZEEMAN effect spectroscopies. A brief introduction to the hyperfine structure and its applications in laser cooling of atoms, BEC, atomic clocks etc. will be pointed out.

COURSE DETAIL

Unit No.	Topic	Lectures
1	Quantum Mechanics and the Symmetry of the hydrogen atom. Complete set of observables for the non-relativistic Hydrogen atom - radial and angular wavefunctions; Complete set of 'good quantum numbers', associated constants of motion and associated symmetries. The Laplace-Runge-Lenz vector and the Fock SO(4) symmetry of the Hydrogen atom.	5
2	Coupling of Angular Momenta, Clebsch-Gordan Coefficients, Statement and Proof the Wigner-Eckart.	7
3	Relativistic Hydrogen Atom. Foldy-Wouthuysen Transformation of Dirac Hamiltonian	6
4	Identical Particles; Exchange interaction and N-electron systems. The Hartree-Fock Self-Consistent Field Formalism. Koopmans Theorem.	5
5	Perturbative analysis of relativistic interactions in atoms.	2
6	Probing the atom – quantum collisions and photoabsorption processes.	4

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Physics

Additional Reading:

1. Hundred years of Einstein's Photoelectric Effect. http://www.physics.iitm.ac.in/~labs/amp/EPEE_PCD_SV.pdf
2. A Fragmentary Tale of the Atom. http://www.physics.iitm.ac.in/~labs/amp/FTA-PCDSV.pdf

Hyperlinks:

http://www.physics.iitm.ac.in/~labs/amp/

Coordinators:

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7	Photoionization cross-section and angular distribution of the photoelectrons.	5
8	Effects of applied electromagnetic fields. Stark effect. Zeeman effect (normal and anomalous) in atomic spectroscopy, Paschen-Back effect. Hyperfine structure. Introduction to laser cooling of atoms and Bose-Einstein condensation.	5

Illustrative Problem Sets for Tutorials that can be used for this course are available at: http://www.physics.iitm.ac.in/~labs/amp/homepage/courses.html

References:

- Bransden, B.H. and Joachain, C.J., Physics of atoms and molecules, Benjamin-Cummings (2003)
- Bjorken, J. and Drell, S., Relativistic Quantum Mechanics, McGraw–Hill (1965).