PHY-472 Atomic and Molecular Physics

Credit Hours: 3-0

Prerequisite: None

Course Objectives: The main objective of this course is to build the foundation of Physics of atoms and molecules such as atomic and molecular spectra of atoms, furthermore detailed calculation of selection rules will introduce to the students from which they can easily analyze the spectra of atoms and molecules.

Core Contents: Review of one electron system, the electromagnetic field and its interaction with charged particles, Deriving selection rules for one electron atoms, The Schrödinger Equation for two electron atoms, Spin wave functions and role of Pauli Exclusion Principle, The Hartree Fock approximation and the self-consistent field, central Field approximation for many electron atoms, Hartree Fock methods and self-consistent field, Born Oppenhimer approximation, The rotation and vibration of
diatomic molecules.

Detailed Course Contents: Atomic molecular and nuclear physics is of fundamental importance in physics. It is the most direct application of quantum mechanics. Moreover, atomic and molecular structure is the basics for all that we know about matter. In order to understand e.g. condensed matter, nuclear and particle physics, one must first learn the basics in atomic and molecular physics. In this course we begin our journey by reviewing Hydrogen atom. Concrete applications of perturbation theory and variational method are given when one starts with a central field approximation. The treatment of molecules are to start with diatomic and first develop the analytical expression necessary for the hydrogen molecular ion in both linear combination of atomic orbitals and Hund-Mulliken method. Moreover study of vibrational and rotational structure of diatomic molecules is also included.

Course Outcomes: On the successful completion of the course, students will able to

- Analyze the atomic spectra of atoms and molecules.
- Implement the selection rules to investigate the allowed Transitions.

Textbooks:

1. Physics of Atoms and Molecules by B. H. Bransden and C. J. Joachain,, McGraw Hill, 2nd ed. 2003 (BJ)
2. An Introduction to Nuclear and Particle Physics, A. Das and T. Ferbel, World Scientific, 2nd ed. 2005 (DF)

Reference books:

1. An Introduction to Atomic and Molecular Physics, Wolfgang Demtröder, McGraw-Hill, sixth-edition 2003
2. D. H. McIntyre, Quantum Mechanics, 2nded. Pearson Addison Wesley 2012.

Weekly Breakdown		
Week	Section	Topics
1	BJ 4.1	The electromagnetic field and its interaction with charged particles
2	BJ 4.2	The transition rates and dipole approximation
3	BJ 4.3, 4.5	Dipole approximation and Einstein Coefficients
4	BJ 4.5, 4.8	Parity and Orbital parity, Deriving selection rules for one electron atoms
5	BJ 4.8	Deriving selection rules for one electron atoms, Photoelectric effect, Review of indistinguishable particles
6	BJ 6.1-6.3	The Schrödinger Equation for two electron atoms, Spin wave functions and role of Pauli Exclusion Principle
7	BJ 6.4-6.5	The independent particle model, Variational method
8	BJ 6.6	The ground-state of two electron atoms
		Midterm Exam
9	BJ 7.1	Central Field approximation for many electron atoms
10	BJ 7.4	The Hartree Fock approximation and the self consistent field.
11	BJ 9.1-9.2	General nature of molecular structure, The Born-Oppenheimer separation of Diatomic molecules
12	BJ 9.4	Electronic structure of diatomic molecules: Hydrogen Molecular Ion (Linear Combination of Atomic Orbitals)
13	BJ 9.4	Hydrogen Molecular Ion: Exact Solution
14	BJ 9.4	Molecular Hydrogen: Hund-Mulliken method/Molecular orbital treatment
15	BJ 10.1-10.3	Rotational energy levels of diatomic molecules, Vibrational spectra of diatomic molecules