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Introduction to Atomic and Molecular Physics and Quantum Collisions

Course code: FSC410133

Credit hours: 4

Duration: 18 weeks

DESCRIPTION: Hydrogen atom. Atoms with more than one electron. Atomic polarizability. Diatomic and polyatomic molecules. Scattering of a particle by a potential. Method of partial waves. Effective range theory. Zero range potential method.

COURSE CONTENT:

1. Hydrogen atom: Schroedinger equation for one electron atoms. Radial eigenfunctions and the discrete spectrum. Radial eigenfunctions and the continuous spectrum. Wavefunctions in the momentum representation: discrete and continuum spectrum. Fine and hyperfine structure of the hydrogen atom.
2. Atoms with more than one electron: Schroedinger equation for atoms with more than two electrons: orto and para states. Electronic configurations for two electron atoms. Central field approximation. The Thomas-Fermi model. Electronic configurations for atoms with N electrons. The Hartree-Fock method.
3. Atomic polarizability: Parameters of molecular response. The static electric polarizability. Polarizability and molecular properties. Polarizabilities and molecular spectroscopy. Polarizabilities and dispersion forces. The relative permittivity and the electric susceptibility. Polar molecules. Refractive index.

4. Diatomic molecules: Schroedinger equation for molecular systems: nuclear and electronic motions. Rotational states of diatomic molecules. Vibrational states of diatomic molecules. Group theory applied to molecular physics. Electronic configurations of diatomic molecules. Molecular electronic states and electronic transitions.

5. Scattering of a particle by a potential: Schroedinger equation and the boundary conditions for a scattering problem. Cross section as the ratio between probability current densities. Differential and integral cross sections.

6. The method of partial waves: Central potential and the method of partial waves. Central potentials and good quantum numbers. Partial wave analysis. Optical theorem and unitarity. Phase shifts: attractive and repulsive potentials. How to calculate the phase shifts. Relations between the laboratory, body and center of mass reference frames. Resonances. Virtual states.

7. Effective range theory: Effective range theory. Modified effective range theory.

8. The zero range potential method (ZRP): Electron-atom and positron-atom scattering in the ZRP method. Vibrational and rotational excitation via ZRP method.

BIBLIOGRAPHY:

1. Physics of atoms and molecules. B.H. Bransden and C.J. Joachain, John Wiley & Sons, Inc., New York, 1983.
2. Quantum Mechanics of One-And Two-Electron Atoms. Hans A. Bethe and Edwin E. Salpeter, Springer Verlag, Academic Press Inc., Berlin 1957.
3. Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Thoery. Attila Szabo and Neil S. Ostlund, Dover Publications, Inc., Mineola, New York, 1989.
4. The Fundamentals of Atomic and Molecular Physics. Robert L. Brooks, Springer, New York, 2013.
5. Atoms, Molecules and Photons: An Introduction to Atomic-,Molecular- and Quantum-Physics. Wolfgang Demtroeder, Springer-Verlag, Berlin, 2006.
6. Molecular Physics: Theoretical Principles and Experimental Methods, Wolfgang Demtroeder, WILEY-VCH Verlag GmbH & KGaA, 2005.
7. Atomic Astrophysics and Spectroscopy. Anil K. Pradhan and Sultana N. Nahar, Cambridge University Press, Cambridge, 2011.

8. Molecular Quantum Mechanics. P.W. Atkins and R.S. Friedman, OUP Oxford, 2011.
9. Atoms and Molecules, Mitchel Weissbluth, Academic Press, Inc., 1978
10. Microwave Molecular Spectra, Walter Gordy and Robert L. Cook, John Wiley & Sons, Inc, 1984.
11. The Theory of Intermolecular Forces. Anthony Stone, Oxford University Press, 2nd edition, 2013.
12. Molecular Spectroscopy. Ira N. Levine, John Wiley & Sons, Inc., 1975.