Course: M.Sc (Physics)

Semester	3
Paper Number	9 (MPHC4301)
Paper Title	Solid State Physics and Atomic and Molecular Physics
No. of Credits	6
Course description/objective	**Group A:** This core course is designed to provide the next level of learning after the UG course in solid state physics (SSP) so that all students irrespective of their future specialization can achieve a thorough understanding in the basics as wells as some advanced areas. **Group B:** To make students appreciate that quantum mechanics applied to atoms and molecules can explain and predict many of their structural properties.
Course Outcome	**Group A** CO1: A complete revision of the basics of Crystallography along with the nearly crystalline phases like quasicrystals and liquid crystals is very helpful for all students in grabbing later the ideas and concepts in SSP. CO2: Basics of Band theory are taught at advanced level with modern issues like 2D materials. CO3: Properties like Optical, Electronic & Electrical, Thermal and Magnetic are explained in detail. CO4: Defect studies is a very important tool in materials research and a chapter is dedicated on this. CO5: A critical phenomena like Superconductivity is explained at the advanced level with the BCS theory and the existence of band gap. **Group B** CO 1: Students will be able to explain atomic spectra at different stages of resolution. CO 2: Students will be able to explain spectra of di-atomic molecules and will be able to extract information regarding bond-length, anharmonicity constant, dissociation energy from the spectra. CO 3: Students will be able to explain Electron spin resonance and Nuclear magnetic resonance spectra.
Syllabus	**Group A: Solid State Physics** Recapitulations of crystal structures, brief overview of quasi crystals and liquid crystals [2 lectures] Band theory of solids: Bloch equation, empty band, nearly free electron (NFE) theory, band gap, tight binding approximation (TBA), Slater-Koster LCAO approach; effective mass of an electron in a band, concept of holes, classification of metal, semiconductor and insulator, 2D materials, Landau levels. [8 lectures] Dielectric properties of solids: Complex dielectric constant and dielectric losses, relaxation time, classical theory of electronic polarization and optical absorption, ferroelectricity. [4 lectures]

	Electronic & Thermal properties of solids: The Boltzmann transport equation and relaxation time, electrical and thermal conductivity of metals, Wiedemann–Franz law, thermal expansion; Magnetoresistance and Hall effect. [4 lectures] Magnetic properties of solids: Quantum theory of paramagnetism, spin para-magnetism – Pauli theory. Ferromagnetism: Stoner's criterion, Curie-Weiss law, Temperature dependence of saturation magnetization, Heisenberg's exchange interaction, Ferromagnetic domains, Magnetic anisotropy, Ferrimagnetism and Anti-ferromagnetism, Longitudinal and Transverse relaxation times, Hyperfine field. [7 lectures] Imperfections in solids: Lattice imperfections, vacancies and interstitial defects, dislocations, colour-centres, photoconductivity, luminescence and phosphors, Order-disorder phenomena in binary alloys, Bragg-Williams theory, extra specific heat, superlattice. [5 lectures] Superconductivity: Phenomenological description of superconductivity, Cooper pairs, BCS theory- expression for energy gap, Josephson effect (qualitative), high-Tc superconductors (qualitative). [6 lectures] **Group B: Atomic & Molecular Physics** Quantum states of an electron in an atom, electron spin [5 lectures] Relativistic corrections for energy levels of hydrogen atom, hyperfine structure, isotopic shift, width of spectral lines [5 lectures] Interaction of hydrogen atom with EM-radiation: induced absorption and emission, transition rates, selection rules [5 lectures] Spectrum of helium and alkali atom, LS and JJ couplings [4 lectures] Electron spin resonance, nuclear magnetic resonance, chemical shift [3 lectures] Molecular structure: molecular Hamiltonian, Born-Oppenheimer approximation, calculation of bond length and dissociation energy, solution of nuclear equation, molecular rotation, rigid and non-rigid rotator, centrifugal distortion, molecular vibration, harmonic oscillator approximation, anharmonicity, Interatomic potentials: Lennard-Jones, Morse potential.

	[8 lectures] Molecular spectra: Franck-Condon principle, electronic, vibrational, rotational and Raman spectra of di-atomic molecules, selection rules. [6 lectures]
References	**Group A:** 1. Solid State Physics by N. W. Ashcroft & N. D. Mermin 2. Solid State Physics by H. Ibach & H. Lüth 3. Introduction to Solids by L. V. Azaroff 4. Introduction to Superconductivity by M. Tinkham 5. Principles of the Theory of Solids by J. M. Ziman **Group B:** 1. Physics of Atoms and Molecules by B.H.Bransden and C.J.Joachain 2. Fundamentals of molecular spectroscopy by Colin N. Banwell and Elaine M. McCash 3. The Fundamentals of Atomic and Molecular Physics by Robert L Brooks 4. Basic Atomic and Molecular Spectroscopy by J Michael Hollas 5. Atomic and Molecular Spectroscopy: Basic Aspects and Practical Applications by Sune Svanberg 6. An Introduction to Atomic and Molecular Physics by Wolfgang Demtroder
Evaluation	Total: 100 CIA: 10 (Group A) + 10 (Group B) End Semester Examination: 40 (Group A) + 40 (Group B)