Course: M.Sc (Physics)

Semester	2
Paper Number	5 (MPHC4201)
Paper Title	Mathematical Physics II and Quantum Mechanics II
No. of Credits	6
Course description/objective	**Group A:** This is a course on mathematical physics divided into two main parts: study of differential equations and group theory. The students will learn to solve ordinary and partial differential equations using certain standard techniques. In the group theory part, students will learn about discrete groups, group representation, Lie group and Lie algebra. This course expects to equip a student to apply techniques of solving differential equation and concepts of group theory for physical problems. **Group B:** Understand why approximation techniques are necessary in QM. Develop skills in handling problems with continuously varying potentials. Understand the splitting of energy levels and transition probabilities, In particular the Fermi golden rule has wide applications in both relativistic and non-relativistic quantum theories. Appreciate the role of symmetries in the quantum world, and the constraints they enforce in the formulation and outcome of theories. Novel concepts like discrete transformations and particle indistinguishability are learnt for the first time in formal context.
Course Outcome	**Group A** CO1: The students learn about solving ordinary differential equations using method of variation of parameters CO2: The concepts of Sturm-Liouville problem and integral transform are discussed. CO3: The students are equipped with the technique of solving partial differential equations arising in certain physical problems. CO4: The students are exposed to different concepts of discrete group theory and group representation and they should be able to apply these concepts for physical systems. CO5: The students get a brief exposure to Lie groups and Lie algebras with emphasis on SU(2) and SU(3). **Group B** CO1: learn why approximate methods are necessary in QM and solve time independent problems that are difficult or impossible to solve otherwise to various orders. CO2: Solve problems with continuously varying potentials using WKB approximation. CO3: Understand and apply the physics behind transitions between energy levels through time-dependent theory. CO4: Understand the significance of continuous and discrete symmetries in the context of QM. CO5: Understand the importance of particle indistinguishability in Quantum Mechanics.

Syllabus	Group A: Mathematical Physics–II (Group Theory and Differential Equations) Ordinary differential equations, second order homogeneous and inhomogeneous equations: Wronskian, general solutions (recap), basic idea of singularities, particular integral using the method of variation of parameters. [4 lectures] Sturm Liouville (SL) problem, SL operators, expansions in orthogonal functions, Rodrigues formula, Special functions, Recurrence relations and generating functions. [5 lectures] Idea of Integral Transforms: Kernel, applications. [4 Lectures] Partial Differential Equations: Partial differential equations in Physics: Laplace, Poisson and Helmholtz equations; diffusion and wave equations. Applications. [5 lectures] Group Theory: Recapitulation of basic concepts: Sets, maps, equivalent relations and classes, homomorphism and isomorphism. [2 lectures] Groups: Definition of group, cyclic groups and its generators, permutation groups, alternating groups, Cayley's theorem, Conjugate elements and associated equivalence classes. [4 lectures] Group representations: faithful and unfaithful representations, equivalent representations. Reducible and irreducible representations. Character of a representation. Schur's lemmas, orthogonality theorems, Character tables and applications [6 lectures] Lie groups and Lie algebras: SU(2) and SU(3) Groups and their corresponding Lie algebras. Introduction to Lorentz and Poincare groups. [6 lectures] **Group B: Quantum Mechanics–II** Approximation methods: Time-independent perturbation theory, first and second order corrections to the energy eigenvalues, first order correction to the eigenvectors, one dimensional harmonic oscillator perturbed by linear, quadratic and cubic potentials. Degenerate perturbation theory, application to the one-electron system – relativistic mass correction, spin- orbit coupling (L-S and J-J), Zeeman effect and Stark effect. Variational method: He atom as an example, first order perturbation, exchange degeneracy, Ritz principle for excited states for He atoms. [10 lectures] The WKB approximation, Time-dependent perturbation theory: Interaction picture, constant and harmonic perturbation – Fermi's Golden rule, sudden and adiabatic

	approximation. [8 lectures] Symmetries in quantum mechanics: Conservation laws and degeneracy associated with symmetries. Continuous symmetries – space and time translations, rotations. Discrete symmetries – parity and time reversal. [9 lectures] Identical Particles: Meaning and consequences, symmetric and antisymmetric wavefunctions, Slater determinant, symmetric and antisymmetric spin wavefunctions of two identical particles, Many-electron atoms: central field approximation. [9 lectures]
References	Group A: 1. G. Arfken and H. J. Weber, Mathematical Methods for Physicists, Academic Press, 6th Edition, Indian Edition, (2005). 2. P. Dennerey and A. Kryzwicki, Mathematics for Physicists, Dover (Indian Edition), (2005). 3. K. F. Riley, M. P. Hobson and S. J. Bence, Mathematical Methods for Physics and Engineering, Cambridge University Press (Cambridge Low-priced Edition) (1999). 4. Special Functions for Scientists and Engineers: W. W. Bell (D. Van Nostrand Co. Ltd.) 5. The Mathematics of Physics and Chemistry: H. Margenau and G. M. Murphy (Affiliated East-West Press Pvt. Ltd.) 1. Group Theory in Physics Vol 1 & 2, J. F. Cornwell, Academic Press 2. Group Theory and its Application to Physical Problems, M. Hamermesh, Dover Publications 3. Lie Group for Pedestrians, H. J. Lipkin (Dover Publications, Inc.) 4. Elements of Group Theory for Physicists, A. W. Joshi (New Age International Publ.) **Group B:** 1. Quantum Mechanics: Vol 2; C. Cohen-Tannoudji, B. Diu, F. Laloe; Wiley. 2. Modern Quantum Mechanics: Vol 2; J. J. Sakurai; Pearson. 3. Quantum Mechanics: Vol 2; A. Messiah; Dover.
Evaluation	Total: 100 CIA: 10 (Group A) + 10 (Group B) End Semester Examination: 40 (Group A) + 40 (Group B)