MPHC4201

Mathematical Physics–II and Quantum Mechanics-II

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]

References:

(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.)

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]

References:

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: 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:

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.