25SC807 Group Theory Methods in Physics 3-1-0-4

Objective:

To equip PhD scholars with the mathematical framework of group theory to analyse symmetries, conservation laws, and fundamental interactions in physical systems.

Unit – I Discrete Groups and Basic Structures

Introduction to discrete groups, subgroups, generators, and conjugacy classes. Symmetric groups and permutation groups with emphasis on cycle notation. Construction and properties of direct product groups and semi-direct product groups. Basic understanding of how discrete group structures underpin physical symmetries in various systems.

Unit – II Molecular Symmetries and Representations

Symmetries of molecules and introduction to point groups. Use of stereographic projection for visualizing molecular symmetry elements. Matrix representations of finite groups, reducible and irreducible representations. Great Orthogonality Theorem and construction of character tables. Mulliken notation and its role in labelling irreducible representations in molecular symmetry analysis.

Unit – III Representation Theory in Physical Applications

Tensor products and projection operators. Symmetry considerations in defining observables and deriving selection rules. Application of group theory to molecular vibrations and normal modes. Interpretation of spectroscopic activity using symmetry arguments in IR and Raman spectra.

Unit – IV Continuous Groups, Lie Algebras, and Physical Symmetries

Introduction to continuous groups and their generators. Lorentz transformations and symmetry in relativistic physics. Structure and properties of orthogonal groups and associated Lie algebras. Unitary groups including SU(2) and SU(3), with introduction to weight vector and root vector diagrams. Application of the Wigner-Eckart theorem to quantum mechanical systems. Examples from the quark model, baryon and meson classification under SU(3), hydrogen atom, and the role of dynamical symmetry in atomic systems.

Textbooks:

1. Georgi H., Lie Algebras in Particle Physics.
2. Mukhi S. and Mukunda N., Introduction to Topology, Differential Geometry and Group Theory for Physicists.

References:

1. Herzberg, G., & Teller, E. (1933). Schwingungsstruktur der Elektronenübergänge bei mehratomigen Molekülen. *Zeitschrift für Physik, 21*(5), 410–446. https://doi.org/10.1007/BF01342390.
2. Gell-Mann, M. (1964). Symmetries of baryons and mesons. *Physical Review, 125*(3), 1067–1084. https://doi.org/10.1103/PhysRev.125.1067

Outcomes:

CO	Course Outcomes
CO01	Understand the structure of discrete groups, subgroups, generators, and conjugacy classes. Learn how this form the basis for symmetry operations in physical systems
CO02	Apply matrix representations, character tables, and projection operators. Analyze molecular point groups and predict spectroscopic behavior.
CO03	Use group-theoretical tools to derive selection rules, construct observables, and study vibrational modes. Interpret their significance in quantum systems.
CO04	Explore continuous groups, Lorentz and unitary transformations, and Lie algebras. Apply these concepts to quantum mechanics, particle physics, and symmetry classifications.

Evaluation Pattern:

Category	Marks
Quizzes(3)	30
Assignments(2)	20
End-sem	50