

PHY-933 Many Body Physics

Credit Hours: 3-0

Prerequisite: None

Course Objectives:

This course introduces students to topics that are traditionally left out in an introductory quantum mechanics course, such as, many-body quantum mechanics, second quantization, quantum fluids Bose-Einstein condensation and selected topics of relativistic quantum mechanics. Path Integral Formalism, Feynman path integral

Core Contents:

The main contents of this course include the many-body quantum mechanics, system of identical particles, second quantization, symmetrization postulate, Elementary Theory of the Electron Gas, Hamiltonian Ground State Energy in the Hartree–Fock Approximation, quantum fluids and Bose-Einstein condensation. Moreover, it includes the selected topics of relativistic quantum mechanics, such as, the Klein–Gordon equation, the Dirac equation, Lorentz transformations and Lorentz covariance of the Dirac equation, Path Integral Formalism: Equivalence with Schrodinger equation, Gaussian and Feynman path integrals, Landau Levels and Barray Phases

Detailed Course Contents:

The detailed contents are given in the table below along with week-wise breakdown.

Textbooks:

1. F. Schwabl (FS), Advanced Quantum Mechanics, 3rd edition, Springer 2005.
2. R.Shankar, (RS), **Principles of Quantum Mechanics**, 2nd edition, (Springer, 1994).

Reference Books:

1. E. Manoukian, A wide spectrum, 1st edition Springer 2006.
2. J.J. Sakurai, Advanced Quantum Mechanics, Addison Wesley 1967.

3. P. Coleman, Introduction to many-body physics, Cambridge University Press 2011.

Weekly Breakdown		
Week	Section	Topics
1	FS 1.1	Introduction to second quantization approach, Identical Particles, Many-Particle States, and Permutation Symmetry
2	FS 1.1, 1.2	States and Observables of Identical Particles, Examples, Completely Symmetric and Antisymmetric States
3	FS 1.3	Bosons, States, Fock Space, Creation and Annihilation Operators, The Particle-Number Operator, General Single- and Many-Particle Operators
4	FS 1.4	Fermions, States, Fock Space, Creation and Annihilation Operators Single- and Many-Particle Operators
5	FS 1.5, 1.6	Transformations Between Different Basis Systems, Field Operators, Field Equations, Momentum Representation, Momentum Eigenfunctions and the Hamiltonian, Fourier Transformation of the Density, The Inclusion of Spin
6	FS 2.1	Noninteracting Fermions, The Fermi Sphere, Excitations, Single-Particle Correlation Function, Pair Distribution Function, Pair Distribution Function, Density Correlation Functions, and Structure Factor
7	FS 2.2	Ground State Energy and Elementary Theory of the Electron Gas, Hamiltonian Ground State Energy in the Hartree–Fock Approximation, Modification of Electron Energy Levels due to the Coulomb Interaction
Mid Term		
8	FS 2.3, 3.1	Hartree–Fock Equations for Atoms, Free Bosons, Pair Distribution Function for Free Bosons, Two-Particle States of Bosons
9	FS 3.2	Weakly Interacting, Dilute Bose Gas, Quantum Fluids and Bose–Einstein Condensation, Bogoliubov Theory of the Weakly Interacting Bose Gas, Superfluidity

10	FS 4.1,4.2,4.3, 4.4,4.5	Scattering and Response, Density Matrix, Correlation Functions, Dynamical Susceptibility, Dispersion Relations, Spectral Representation
11	FS 4.6,4.7,4.8,4.9	Fluctuation–Dissipation Theorem, Examples of Applications, Symmetry Properties, General Symmetry Relations, Symmetry Properties of the Response Function for Hermitian Operators, Sum Rules
12	RS 21.1	Path Integral Formalism: Equivalence with Schrodinger equation, Gaussian and Feynman path integrals
13	RS 21.1	Feynman path integral: Free Particle, Under gravity, Simple harmonic oscillator in path integral representation,
14	RS 21.1	Landau Levels and Barray Phases, Imaginary time formulism
15	RS 21.2	Tunnelling by Path integrals, Imaginary Time Path Integrals and Quantum Statistical Mechanics