PHY-443 Quantum Field Theory

Credit Hours: 3-0

Prerequisite: None

Course Objectives: The purpose of this course is to give an overview of the fields from where the fundamental particles being derived. In this course students will learn different techniques such as field quantization, Feynman rules and apply. This course will help student to tackle research problems in the field of high energy physics, condensed matter physics, Quantum optics and quantum information.

Core Contents: Relativistic quantum mechanics, Elements of Classical fields, Scalar field and its quantization, Dirac field and its quantization, interacting fields, Deriving Feynman rules using canonical quantization approach, Solving Feynman diagrams of Scalar field theory at tree level, Quantum Electrodynamics (QED)+ processes at tree level.

Detailed Course Contents: Klein Gordon Equation and its Solution, Issues with Klein Gordon equation , Dirac equation and its solution, Elements of Classical Field Theory, Lagrangian and Hamiltonian Theory, Noether's Theorem, Example of Noether's Theorem, Stress Energy Tensor, Klein Gordon Field as an harmonic oscillator, Canonical Quantization of Scalar field, Klein Gordon Field in a space time, Causality ; The Klein Gordon Propagator, Dirac Equation and its Solution, Fermion spin sums, Quantization of Dirac Field, Fermion Propagator, Discrete symmetries of Dirac Theory; Parity, Charge conjugation and Time Reversal, Interacting Fields, The interaction picture, Dyson Formula, A first look at Scattering, Wick's Theorem : Recovering Propagator as an example, Wick's Theorem:, Feynman diagrams, Nucleon-Nucleon Scattering, Elementary processes in Quantum Electrodynamics. Introduction to one loop diagrams.

Course Outcomes: At the end of the course Student will be able to understand

- Relativistic quantum mechanics
- the quantization of field using canonical quantization
- the Feynman rules and will apply to different scattering and decay processes.
- Basic concept of one loop diagrams.

Textbooks:

1. Modern Particle Physics, Mark Thompson , Cambridge University Press, 2013.
2. **A Modern Introduction to Quantum Field Theory,** Michele Maggiore,

Oxford University Process, 2005.

Reference books:

1. Michael E. Peskin, Daniel V. Schroeder, Introduction to Quantum Field Theory, 9th ed. John Wiley and sons 2011.
2. Matthew D. Schwartz (MDS), Quantum Field Theory and the Standard Model, Cambridge University Press 2014.
3. Mark Srednicki (MS), Quantum Field Theory, Cambridge University Press 2012.
4. Steven Weinberg, The Quantum Theory of Field, Cambridge University Press, 1995.

Weekly Breakdown		
Week	***Section***	***Topics***
1.	Handouts, MT 4.1	Review of Special relativity, Relativistic notation, Klein Gordon Equation and its Solution, Issues with Klein Gordon equation
2.	MT 4.2	Construction of Dirac equation, Solution of Dirac equation.
3.	MT 4.2-4.4	Positive and negative energy solutions, Probability density and probability current.
4.	Handouts	Revisit Lagrangian formalism of system of particles and fields, Transition from Discrete to continuous system.
5.	MM 3.1	Elements of Classical Field Theory, Equation of motion for Classical fields, Hamiltonian formalism of classical fields.
6.	MM 3.2	Noether's Theorem, Conservation of electric charge and conservation of energy
7.	MM 3.3,4.1	Klein Gordon field as an harmonic oscillator, Quantization of real and complex scalar field.
8.	Handouts, MM 5.1	Interacting Fields, The interaction picture, Dyson Formula.
		Midterm Exam
9.	MM 5.4-5.5	The Feynman Propagator (Wick's Theorem), Feynman diagrams, Nucelon-Nucleon Scattering.
10.	MM 3.4, Handouts	Spinor and Weyl Fields, Dirac Equation, Dirac Matrices and Dirac bilinears.

11.	MM 4.2	Quantization of Dirac field, Discrete symmetries of Dirac theory.
12.	Handouts MM 5.5	Fermionic propagator, Feynman rules of Fermions and gauge bosons
13.	MM 6.1-6.2	Relativistic and non relativistic normalization, Computation of Decay rates
14.	MM 6.3, Handouts	Computation of Scattering cross-sections, Feynman rules for Quantum Electrodynamics.
15.	Handouts	Computation of Quantum electrodynamics processes, Introduction to one loop diagrams.