PHY-902 Quantum Field Theory-I

Credit Hours: 3-0

Prerequisite: PHY-803 Quantum Mechanics

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, dimensional regularization, and renormalization. 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: Elements of Classical fields, Scalar field and its quantization, Dirac field and its quantization, interacting fields, Deriving Feynman rules using canonical quantization approach, Quantum Electrodynamics (QED)+ processes at tree level, Regularization and renormalization, QED vertex correction and computation of beta function of QED

Detailed Course Contents: 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, Helicity Structure, Formal Structure of Electron vertex function, Evaluation of Electron vertex function using Feynman Parameterization, Introduction to Renormalization, Evaluation of Electron Self-Energy, Renormalization of the Electric

Charge, Overview of Charge Renormalization, Introduction to Dimensional Regularization, Evaluation of vacuum polarization diagram using dimensional regularization, beta function for QED

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

- the quantization of field using canonical quantization
- the Feynman rules and will apply to different scattering and decay processes.
- the dimensional regularization and re-normalization
- and apply these techniques to different research problems

Textbook: Michael E. Peskin, Daniel V. Schroeder, Introduction to Quantum Field Theory, 9th ed. John Wiley and sons 2011.

Reference Books:

1. Matthew D. Schwartz (MDS), Quantum Field Theory and the Standard Model, Cambridge University Press 2014.

2. Mark Srednicki (MS), **Quantum Field Theory**, Cambridge University Press 2012.

3. Steven Weinberg, The Quantum Theory of Field, Cambridge University Press, 1995.

Weekly Breakdown		
Week	***Section***	***Topics***
1.	PS 2.1-2.2	Elements of Classical Field Theory, Lagrangian and Hamiltonian Theory, Noether's Theorem, Example of Noether's Theorem, Stress Energy Tensor.
2.	PS 2.3-2.4	Klein Gordon Field as a Harmonic Oscillator, Canonical Quantization of Scalar field, Klein Gordon Field in a space time, Causality; The Klein Gordon Propagator.
3.	PS 3.2-3.3,3.5	Dirac Equation and its Solution, Fermion spin sums, Quantization of Dirac Field
4.	PS 3.5-3.6	Fermion Propagator, Discrete symmetries of Dirac Theory; Parity, Charge conjugation and Time Reversal.

5.	PS4.1-4.2	Interacting Fields, the interaction picture, Dyson Formula, A first look at Scattering
6.	PS 4.3 -4.4	Wick's Theorem: Recovering Propagator as an example, Wick's Theorem: Feynman diagrams, Nucleon-Nucleon Scattering
7.	PS 4.5-4.6	Cross-sections and S-matrix, calculations of S-matrix from Feynman diagrams.
8.	PS 4.7-4.8	Feynman Rules for Fermions and Feynman Rules for Quantum Electrodynamics.
9.	PS 5.1-5.2	Elementary processes in Quantum Electrodynamics, Helicity Structure
10.	PS 5.4-5.5	Electron-Muon Symmetry, Compton Scattering
11.	PS 6.2-6.3	Formal Structure of Electron vertex function, Evaluation of Electron vertex function using Feynman Parameterization.
12.	PS 7.1	Introduction to Renormalization, Evaluation of Electron Self-Energy.
13.	PS 7.3-7.4	The Optical Theorem, The Optical Theorem for Feynman Diagrams, Ward Takahashi Identity.
14.	PS 7.5	Renormalization of the Electric Charge, Overview of Charge Renormalization.
15.	PS 7.5	Introduction to Dimensional Regularization, Evaluation of vacuum polarization diagram using dimensional regularization, beta function for QED.