Approved in 37th BoA Meeting (29-10-2020)

Course Name: Quantum Field Theory

Course Number: PH 606

Credits: (3-0-0-3)

Prerequisites: Quantum Mechanics (PH513), Mathematical Physics (PH511).

Intended for: M.Sc. (Physics), Ph.D., I-Ph.D., B.Tech 3rd and 4th Year.

Distribution: Elective for I-Ph.D., Ph.D., M.Sc., B.Tech 3rd and 4th Year.

Preamble: Quantum field theory forms one of the central pillars of modern theoretical physics. The objective of the proposed course is to introduce students to some key ideas and methods in quantum field theory and also discuss relevant applications.

Course Outline: The course will start with a review of second quantization and some mathematical tools such as functional analysis. Then the course will move on to more formal and rigorous treatment of quantum fields. Important ideas of quantization of fields, symmetries, Feynman diagrams, and propagators will be introduced with several examples in the first five modules (canonical quantisation formulation). The instructor can choose either of the Module 6 (each of which is aimed at specific applications).

Modules:

Module 1: Mathematical preliminaries, Lagrangian and Hamiltonian density, second quantization, functionals, path integrals, functional field integrals, coherent states for bosons and fermions. [7 hours]

Module 2: Classical fields, Klein-Gordon field, massless scalar field theory, massive scalar fields, Phi-4 theory, complex scalar fields. [5 hours]

Module 3: Schrodinger, Heisenberg, and interaction pictures, time-evolution operator, translations and rotations in space-time, transformations of quantum fields, symmetries and conservation laws, Noether's theorem. [8 hours]

Module 4: Canonical quantization of fields with examples, normal ordering, internal symmetries, massive vector fields, polarizations, gauge fields and gauge theory. [7 hours]

Module 5: Propagators and Green's functions, Dyson equation, field and Feynman propagator, Smatrix, perturbation expansion, Wick's theorem, Feynman diagrams. [7 hours]

Module 6 (some applications of field theory in condensed matter physics): Superfluids and fields, Fermi liquid theory, field theory formulation of many-body problem in metals and superconductors, Hartree-Fock energy, random phase approximation, fractional quantum Hall effect. [8 hours]

OR

Module 6 (some applications of field theory in particle physics): Dirac and Weyl equation, spinors, transformation of spinors, quantizing the Dirac field, fermion propagator, quantum electrodynamics (QED), Feynman rules, QED scattering cross sections. [8 hours]

Books:

Text

1. Quantum field theory for gifted amateur, by Lancaster and Blundell, Oxford (2014).
2. Quantum field theory, by Mandl and Shaw, John Wiley and Sons (2010).
3. An introduction to quantum field theory, by Peskin and Schroeder, CRC Press (2018).

References

1. Quantum theory of Fields, Vol.1, by S. Weinberg, Cambridge (1995).
2. Quantum field theory, by M. Srednicki, Cambridge (2007).
3. Quantum field theory by M. H. Ryder, Cambridge (1996).

Online resources:

1. David Tong: lectures on QFT http://www.damtp.cam.ac.uk/user/tong/qft.html
2. Lectures on advanced quantum mechanics by Freeman Dyson. https://arxiv.org/pdf/quant-ph/0608140.pdf

Similarity Content Declaration with Existing Courses:

Sl. No.	Course code	Similarity content	Percentage
1)	PH 512 Classical Mechanics	Lagrangian, least action.	< 5%
2)	PH 613 Special topics in Quantum Mechanics	Klein-Gordon and Dirac equation.	< 5%
3)	PH 521 Electromagnetic Theory	Electromagnetic field tensor.	< 5%
4)	PH 613 Special topics in QM.	Klein-Gordon and Dirac equation	<5%

Justification for new course proposal if cumulative similarity content is > 30%: N/A