

PHY639: Advanced Quantum Field Theory, First Course Handout (FCH) Semester 2026-27-II

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(All course related communications and announcements will be posted there)

Preferred mode of conduct : Appointment through email.

Course Description & Objectives: This is the second course on Quantum Field Theory which will deal with key formal developments and features of the QFT formulation.

- **Objective:** To provide a rigorous understanding of loop-level computations in quantum field theories, the renormalization group flow, the path integral quantization of Non-Abelian Gauge Theories (QCD), and the theory of S-matrices.
- **Learning Outcomes:** By the end of this course, students will be able to:
 1. Compute 1-loop radiative corrections (Self-energy, Vertex function) using Dimensional Regularization.
 2. Derive and interpret the Beta-function and running couplings for QED and QCD.
 3. Formulate path integrals for Fermions and Gauge fields (using Faddeev-Popov ghosts).
 4. Understand the consequences of S-Matrix Unitarity and Analyticity.

Lecture outline: $26 \times (t = 75 \text{ Minutes})$

Topics	Details	t
Path integrals & Diagrammatics	Scalar & Fermion, $\det(i \not{\partial} - m)$, Propagator derivation & LSZ reduction	4
Encountering ∞	QED loops (Self-energy, Vertex), $g - 2$, DimReg, Ward Identity, Bremsstrahlung	5
Wilsonian Renormalization	Momentum shells, Fixed points, β -functions, Operator product expansion (OPE), Callan-Symanzik equation, Composite operators	6
Gauge Theory	Non-Abelian gauge fields, Faddeev-Popov, Ghosts, BRST, QCD β -function, Asymptotic Freedom	8
Unitarity	Optical theorem, Spectral density, Cutting rules, Dispersion relations	3

Pre-requisites: PHY685: Quantum field theory - 1.

Evaluations & Grading Policy:

- **Attendance [15%]:** Attendance is mandatory. A minimum of 75% attendance is required to appear for the End Semester Examination.
- **Quizzes [25%]:** Regular quizzes will be conducted during tutorial hours.
- **Midsemester examination [25%]**
- **Endsemester examination [35%]**

Makeup Policy: Make-up for End-semester exams will be granted only for valid medical or institutional reasons, strictly in accordance with the Institute's policy. No make-up for Mid-semester and Quizzes.

Academic Integrity: Use of unfair means (plagiarism, cheating, unauthorized collaboration) in any evaluation component will lead to severe penalties, ranging from mark deduction to referral to the Senate Student Affairs Committee (SSAC).

Notice board: All announcements and course logistics will be updated in hello.iitk.ac.in.

References :

1. *Quantum Field Theory and the Standard Model*, M. Schwartz, **1.** *Quantum Field Theory Volume 1 & 2*, S. Weinberg **2.** *Quantum Theory of Many-variable Systems and Fields*, B. Sakita **3.** *Quantum Field Theory in a Nutshell*, A. Zee, **4.** *Quantum Field Theory*, M. Srednicki, **5.** *An Introduction to Quantum Field Theory*, D. V. Schroeder and M. Peskin.
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