

## Indian Institute of Technology, Kanpur

### Quantum Field Theory 1 : PHY-685 (2026 Autumn semester)

1. Lectures per week: 2 (Location - Yet to be decided. Timing Monday, Thursday 12:00 PM to 13:30 PM)  
Tutorials per week : 1 (Location - Yet to be decided. Timing Tuesday : 11:00 AM to 12:00 PM)  
Duration of Course: Full Semester
2. Instructor: Sanmay Ganguly (PHY) ([sanmay@iitk.ac.in](mailto:sanmay@iitk.ac.in)) ; Office : 111, Old SAC building, block - A)
3. Course Description:

S. No.	Broad Title	Topics	No. of Lectures
	<b>Why Quantum Field Theory?</b>	Combining quantum mechanics and special relativity. Creation and annihilation operators in multi-particle Hilbert space. The problem with infinities.	<b>2</b>
	<b>Quantum Lorentz Transformation</b>	The unitary representation of Poincare group and the Poincare algebra. The concept of little group. Single particle states as irreducible representation of Poincare group.	<b>2</b>
	<b>Classical Field Theory</b>	Lagrangian and Hamiltonian of systems with field degrees of freedom, equations of motion and Poisson bracket. Global symmetry, Noethers theorem. Energy-momentum tensor and conserved currents. Symmetry generators.	<b>4</b>
	<b>Canonical quantisation of free and interacting scalar theory.</b>	Quantisation in the Heisenberg picture, Causality and propagators, the Feynman propagator, propagator as Green's function. The Kallen-Lehmann representation. S-matrix and asymptotic states, The LSZ reduction formula, Wick's theorem, Feynman diagrams. Position space and momentum space Feynman rules, counting symmetry factors. Connected, disconnected and 1-PI diagrams, computing S-matrix elements and scattering cross-sections for tree level process. Spin-statistics theorem for scalars.	<b>10</b>
	<b>Spin-1/2 fields and its quantisation.</b>	Spin-1/2 representation of Poincare group. The Dirac spinor, Weyl spinor, Majorana spinor and their classical field theories. Dirac's equation and it's solution. Quantisation of spinor field, Wick's theorem and propagator for fermions. LSZ formula for fermions and Feynman rules.. The Kallen-Lehmann representation and spectral functions for fermions. The Yukawa theory at tree level and the Yukawa potential at classical limit. Spin sums, Gamma matrix technology and spin averaged cross-section. Spin-statistics theorem for fermions.	<b>4</b>
	<b>Quantising spin-1 particle</b>	Classical Maxwell theory. Canonical quantisation of free field. Gupta-Bleuler quantisation. Massive vector fields. Coupling of spin-1 field to scalar and fermions. Feynman rules for QED (both scalar and fermionic). LSZ for spin-1 fields. Recovering Coulomb's potential.	<b>4</b>

	<b>Quantum Electrodynamics at tree level</b>	QED processes at tree level, spin and polarization states, trace identities, center of mass frame, photon polarization sums, spin averaged cross-section for 2-body final states. Ward-Takahashi identities, relation between current conservation and gauge invariance. Decoupling of potential ghosts.	<b>4</b>
<b>Total number of lectures:</b>			<b>30</b>

**Pre-requisites:** Quantum Mechanics-2 ( more or less you can handle Sakurai / Shankar ) + Special Relativity ( at level of Chapter 7 of Goldstein's classical mechanics book, 3rd edition / Chapter 11 Jackson's ED book, 3rd edition )

**Evaluation: Assignments: ( 20 Marks) + Mid-sem exam (20 marks) + Performance in tutorials (10 marks) + End-sem exam (50 Marks) = 100 Marks**

**Tutorial evaluation:** Every student, who seeks to credit the course, have to actively participate in the discussions during lectures and tutorials. The performance during tutorial, including participation in questions/discussions, will carry total 10 marks in final evaluation.

**Extra class policy:** The instructor will announce extra lecture hours whenever required. Sometimes, a lecture may shoot off to extra minutes. It's absolutely important to go through every piece of material meticulously in the class. Hence we will spend whatever hours it takes, on the board.  
If you can't stand it, don't come!

#### 4. **Recommended resources:**

##### Books :

1. [An Introduction to Quantum Field Theory. M. Peskin, D. Schroeder. CRC Press, 2019](#)
2. [Quantum Field Theory and the Standard Model. Matthew Schwartz. Cambridge University Press, 2013.](#)
3. [Quantum Field Theory. Mark Srednicki. Cambridge University Press, 2007.](#)
4. [Quantum Theory of Fields, Volume-1. Steven Weinberg. Cambridge University Press, 1995.](#)
5. [Quantum Field Theory , An integrated approach. Eduardo Fradkin, Princeton university press, 2021.](#)
6. [Quantum Field Theory Lectures of Sidney Coleman, World Scientific, 2022.](#)
7. [Quantum Field Theory in a Nutshell, Anthony Zee, 2nd Edition. Princeton University Press, 2010.](#)
8. [Field Theory : A Modern Primer. Pierre Ramond, Taylor & Francis, 1997.](#)

##### Lecture Notes :

1. [David Tong QFT lectures.](#)
2. [John McGreevy Lectures.](#)
3. [Daniel Harlow's lecture notes.](#)