

ICTP DIPLOMA PROGRAMME IN HIGH ENERGY PHYSICS 2014-15

SYLLABUS

Quantum Field Theory - {28 Lectures = 42 hours} K.S. Narain

1. Path Integrals and Quantum Mechanics

Schrödinger and Heisenberg pictures. The kernel, the kernel for small time interval. Convolution. The Path integral. Generating functional of correlation functions.

2. Many Degrees of Freedom and Field Theory Path Integrals

Generalisation to more than one degree of freedom. Quantum field theory. Euclidean space.

3. Perturbation Theory

Gaussian path integrals: finite dimensional integrals, passing to field theory. Turning on the interaction. The Feynman propagator. Leading order calculation of $Z[J]$, the normalisation. Relation to the standard perturbation theory and Wick's theorem, absence of vacuum bubbles.

4. Path Integrals for Fermions

Grassman variables, integration rules. Generating functionals. Quantum field theory of fermions.

5. Gauge Theories

Local gauge symmetry. Vector potentials and covariant derivatives, gauge covariance. Gauge invariant action and field equations. Coupling of fermions.

6. Path Integrals for Gauge Theories

Need for a gauge choice for the photon. A simple model: gauge choice independence. Gauge theory, the Fadeev-Popov trick. Fadeev-Popov ghosts.

7. The Standard Model

The Lagrangian of the Standard Model. The electroweak interaction of leptons. QCD Lagrangian and the electroweak interaction of quarks.

8. The Effective Action

Generating Function $W[J]$ for connected graphs, the effective action, effective equations of motion, leading order corrections to classical dynamics.

9. Perturbation Theory and Diagrammatics

Diagrammatics, effective action upto 2 loops, determining the solution of the effective equations of motion.

10. The Effective Action and low Energy Physics

The effective potential, 1-loop effective action, Goldstone's theorem, the mass matrix.

11. Divergences in Proper Vertices

Diagrammatic rules, diagrams and expressions for 2-pt and 4-pt vertices upto 2-loops. 1-loop

renormalization.

12. Renormalization in ϕ^4 theory

2-pt vertex upto 2-loops, renormalized n-pt. vertices, renormalized action and counter-terms, 1-loop and 2-loop calculations.

13. Dimensional Regularization

1-loop 4-pt vertex in ϕ^4 theory theory, systematics of dimensional regularization, 1-loop renormalization in the MS scheme : 1-loop 2 and 4-pt vertex

14. Power Counting in Field Theory

Canonical dimensions for a scalar field theory, superficial degree of divergence, renormalizable field theories, theories with spinors, theories with vector fields.

15. Renormalization Group Equations

RG equations in ϕ^4 theory, the solution of the RG equation, a scaling argument, high energy behaviour.

16. Analysis of the RG equations in the MS scheme

Behaviour of the solutions of the RG equations, the scaling behaviour of renormalized n-pt vertex at fixed points, independence of physical quantities on the renormalization scale, scheme independence.