# ICTP DIPLOMA PROGRAMME IN HIGH ENERGY PHYSICS 2012-13

## SYLLABUS

## Quantum Filed Theory - {26 Lectures = 39 hours} K.S. Narain

**1. Path Integrals and Quantum Mechanics**
   Schördinger 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 Diagramatics**
   Diagramatics, 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**
   Diagramatic rules, diagrams and expressions for 2-pt and 4-pt vertoices upto 2-loops. 1-loop

renormalization.

## 12. Renormalization in $\phi^4$ 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 $\phi^4$ 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 $\phi^4$ 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.