ICTP DIPLOMA PROGRAMME IN HIGH ENERGY, COSMOLOGY AND ASTROPARTICLE PHYSICS 2015-2016

SYLLABUS

Quantum Filed Theory - {23 Lectures = 34.5 hours} Atish Dabholkar

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 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, Wilson-Fisher fixed point, critical phenomena

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.