Spring 2012

ADVANCED QUANTUM FIELD THEORY

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Mo-We-Fri 10:40 – 11:35 in P123

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This class is for students who have completed a standard course in quantum field theory. The class is both advanced and basic: we discuss topics that one usually does not reach in classes on quantum field theory, but which are basic and fundamental, and which graduate students in particle physics are supposed to be familiar with. These topics are treated from scratch and in detail. The class does not require knowledge of a similar class I taught in the fall 2011 semester, except that I will assume that one knows the BRST formalism. Interested students can obtain from me via email the chapter on BRST symmetry that I used in the first semester and I am willing to give one special lecture to discuss its content. The list of topics is as follows

1.SOLITONS. The classical kink, vortex and monopole solutions. The BPS bound. Supersymmetric extensions. Quantization and one loop corrections to the mass and central charges. Index theorems for the kink, vortex and monopoles. Topological aspects. Duality between point particles and solitons.

2. BASIC SUPERSYMMETRY AND SUPERGRAVITY. The simplest models in four-dimensional Minkowski space: the Wess-Zumino model, super Yang-Mills theory, and simple (N = 1) supergravity. Auxiliary fields. Closure of the super-algebras. Superspace description.

3.UNITARITY.The largest-time equation for unitarity of non-gauge theories. The cutting rules and anti propagators. The BRST-Ward identities of connected graphs for unitarity of gauge theories. Unitarity of spontaneously broken gauge theories. Unitarity after renormalization. Definition of the S matrix from requiring unitarity. Proof that the counter terms for renormalization are local polynomials in the fields and their derivatives. Causality and statistics. Gauge-choice independence of the S-matrix.

4. BACKGROUND FIELD FORMALISM. Background-gauge invariance of quantized gauge theories.The background-gauge invariant effective action. The S-matrix in the background field formalism. Renormalization of background gauge field theories. Extended BRST symmetry of background gauge field theories and gauge-choice independence of the beta function. Two-loop beta function for QCD calculated with the background method.

5.RENORMALIZATION GROUP. Two derivations: one by comparing unrenormalized and renormalized objects, and another by finite rescalings in the renormalized theory. Beta function, anomalous dimensions and running of masses. The one and two loop beta functions in supersymmetric theories.

Typed notes of a forthcoming book will be provided. Grades are determined by an oral exam at the end of the class.