

# Advanced Quantum Gauge Field Theory II

PETER VAN NIEUWENHUIZEN

This course is a continuation of a similar course taught in the spring of 2013, but no knowledge of that course is required for this course. However, some familiarity with rigid supersymmetric (susy) field theories in 4, 3 and 2 dimensions is assumed, and of course a standard class in quantum (gauge) field theory. Grades are determined by a written and an oral exam at the end, and to a lesser extent by homework. Typed notes will be handed out. The set of topics last time was as follows

- BRST symmetry
- Instantons
- Renormalization of QCD and Higgs models
- Anomalies, WZ effective actions and homotopy

The list of topics this year is as follows:

1) THE BACKGROUND FIELD METHOD (BFM). Background gauge invariance of quantum gauge field actions. The S-matrix and the effective action in the BFM. Renormalization in the BFM. Extended BRST symmetry and gauge-choice independence of the beta function. Explicit two-loop calculation of the beta function for QCD using the BFM.

2) SOLITONS. The classical kink, vortex and monopole solutions. The classical BPS bound. Susy extensions. Quantization of solitons, zero modes and moduli (collective coordinates). One loop corrections to the mass and central charge of susy solitons. Index theorems for the spectral densities of susy solitons. The quantum BPS bound. Topological aspects. Duality between point particles and solitons.

3) LOOPS IN SUPERSPACE. Quantization and explicit one-loop calculations of susy gauge theories in superspace and in x-space. Nonrenormalization theorems for N=1, N=2 and N=4 theories. The background field formalism in superspace and renormalization.

4) UNITARITY. The largest-time equation and unitarity of non-gauge field theories. Cutting rules and anti-propagators. BRST-Ward identities for connected graphs. Unitarity of regularized gauge field theories. Unitarity of renormalized gauge theories. Unitarity of spontaneously broken gauge theories. Definition of the S-matrix from unitarity. Proof of locality of counterterms. Causality and statistics. Gauge-choice independence of the S-matrix from the two-largest times equation.

5) EFFECTIVE ACTIONS. Nonlinear realizations of symmetries from coset models. Skyrme models. Renormalization of composite operators, operator mixing and anomalous dimensions of composite operators. An effective action for the nonrenormalizable V-A theory of the weak interactions.

6) HAMILTONIAN QUANTUM GAUGE FIELD THEORY. The Dirac formalism. The BV antifield formalism. Hamiltonian path integrals and gauge fixing. Relation between Lagrangian field theories in one gauge and Hamiltonian field theories in another gauge