ADVANCED QUANTUM FIELD THEORY II. SPRING 2016.

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This course is for graduate students who have followed a standard class in quantum field theory, for example we assume familiarity with the quantization of nonabelian gauge theories, path integrals and loop calculations of Feynman diagrams. The BRST formalism takes a central position, and we assume it to be known, but a simple typed introduction is available on the web (google: Graduate courses in physics at Stony Brook, and then see the link to this course). At the end of the class there will be both a written exam and an oral exam, and there are weekly homeworks. Students are asked to register instead of sitting in. This is part II of this class; part I dealt with Ward identities for proper graphs derived from BRST symmetry, renormalization of QCD and Higgs models using the BRST formalism, anomalies, instantons, and infrared aspects of QCD. These topics are not needed for part II. The list of topics of part II is as follows:

BACKGROUND FIELD METHOD. Gauge fields are decomposed into a classical part and a quantum part; the quantum part is quantized as usual and leads to BRST symmetry, but a classical gauge invariance remains at the quantum level. This method makes quantum calculations much simpler, as we shall demonstrate by computing the 2-loop beta function and proving that it is gauge-choice independent.

UNITARITY FROM THE CUTTING RULES. Ghosts are supposed to cancel the unphysical contributions to the S-matrix from the longitudinal and timelike polarizations of the gauge fields. We show this in perturbation theory by using the BRST-Ward identities for connected graphs. We also discuss the interplay between renormalization and unitarity, and DEFINE the S-matrix such that it is unitary.

SOLITONS. We begin with the classical solitons and their topological properties: the kink, the vortex, and the monopoles and dyons. Next we extend this to supersymmetric (susy) models. Prior knowledge of susy is assumed but students who do not have it can choose a replacement topic (or learn it in this class). Then we discuss quantum corrections to solitons, and compute the one-loop corrections to the mass and central charges of each of these solitons. Finally we discuss the duality between the spectra of ordinary quantum fields and solitonic models.

EFFECTIVE FIELD THEORY. Michael Douglas will give a couple of lectures on nonlinear sigma models and their quantum corrections. As an example of effective field theory the quantum corrections to the nonrenormalizable but quite successful 4-Fermi V-A theory will be worked out.

DIRAC AND ANTIFIELD FORMALISM. The canonical formalism of Lagrange and Hamilton breaks down for gauge theories (and Majorana spinors and other cases.). Dirac developed an extension to deal with these cases, which turns out to be a special case of BRST symmetry. The modern version is an extension of this extension, which is called the Batalin-Vilkovisky (BV) antifield formalism, in which canonical momenta become Lorentz-covariant anticommuting fields.