Advanced Quantum Field Theory (L24)

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Quantum Field Theory (QFT) provides the most profound description of nature we currently possess and is the basic theoretical framework for describing elementary particles and their interactions (excluding gravity). QFT also plays a major role in areas of physics and mathematics as diverse as string theory, condensed matter physics, topology and geometry, astrophysics and cosmology.

This course introduces techniques of path integrals and functional methods to study QFT including gauge theories. Gauge theories are a generalization of electrodynamics and form the backbone of the Standard Model which describes strong, weak and electromagnetic interactions. In a gauge theory, fields have an infinitely redundant description; we can transform the fields by a different element of a Lie group at every point in space-time and yet still describe the same physics. Quantizing a gauge theory requires us to eliminate this infinite redundancy. In the path integral approach, this is done using tools such as ghost fields and BRST symmetry.

Another major component of the course is renormalization. Wilson's picture of renormalization is one of the deepest insights into QFT – it explains why we can do physics at all! The essential point is that the physics we see depends on the scale at which we look. In QFT, this dependence is governed by evolution along the renormalization group (RG) flow. The course explores renormalization systematically using dimensional regularization in perturbative loop integrals. We discuss the various possible behaviours of a QFT under RG flow, showing in particular that the coupling constant of a nonabelian gauge theory can effectively become small at high energies. Known as asymptotic freedom, this phenomenon revolutionized our understanding of the strong interactions. We introduce the notion of an effective field theory that describes the low energy limit of a more fundamental theory and helps parametrize possible departures from this low energy approximation. From a modern perspective, the Standard Model itself is viewed as an effective field theory.

Prerequisites

Knowledge of the Quantum Field Theory course will be assumed. Familiarity with the Symmetries, Particles and Fields course would be helpful for the section on nonabelian gauge theory. The section on the renormalization group has some overlap with the Statistical Field Theory course, but no knowledge of that course will be assumed.

Literature

1. M. Peskin and D. Schroeder, *An Introduction to Quantum Field Theory*, CRC Press (1995).

2. M. Srednicki, *Quantum Field Theory*, CUP (2007). [A pre-publication draft is available at http://web.physics.ucsb.edu/~mark/qft.html.]

3. S. Weinberg, *The Quantum Theory of Fields*, vols. 1 & 2, CUP (1996).

Additional support

Four examples sheets will be provided and four associated examples classes will be given. There will also be a revision class in Easter Term.