UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Quantum Field Theory II

2526-1-F1703Q041

Aims

Knowledge and understanding: The student will complete the knowledge of Quantum Field Theory, getting familiar with the functional approach to theories with matter (fermions) and gauge theories describing fundamental interactions. The student will deepen the knowledge of QED and QCD. The student will get familiar with advanced topics in Quantum Field Theory, like BRST symmetry, symmetries and anomalies, and instantons.

Applying knowledge and understanding: The student will learn to apply Relativistic Quantum Field Theories to the study of Fundamental Interactions, with particular focus on the Standard Model. The student will learn how to apply perturbative techniques to the evaluation of generating functionals and effective actions for gauge theories with matter. The student will be able to study continuous and discrete symmetries of a theory and compute possible anomalies. The student will eventually develop a more formal and mathematical approach to Quantum Field Theory.

Making judgments: The student will develop critical thinking and judgment skills in selecting the most appropriate tool, among those provided during the course, to solve a specific problem.

Communication skills: The student will be expected to acquire a correct and appropriate scientific language suited to the topics covered in the course.

Learning skills: The student will be able to deepen their understanding of specific concepts not covered during the course and to independently pursue advanced study using specialized scientific texts.

Contents

Functional approach to theories with fermions and gauge theories. Perturbative renormalization of QED and QCD. Renormalization group for gauge theories. Anomalies.

Detailed program

Wilsonian effective action. Classification of composite operators.
Functional methods for fermions. Integration on grassmannian variables. Yukawa theory: one-loop renormalization.
Discrete symmetries: parity, time-reversal, charge conjugation. PCT theorem.
Gauge theories. Yang-Mills theories. Path integral formulation. Abelian and non-abelian cases.
Propagator of the gauge fields. Gauge fixing, Faddeev-Popov determinant and corresponding ghosts. BRST quantization.
Perturbative approach to path integral for gauge theories with scalar and fermionic matter. QED: Renormalization and beta functions for QED and QCD. Asymptotic freedom. Banks-Zaks fixed point.
Renormalizability of gauge theories with spontaneous symmetry breaking. Renormalizable gauges vs unitary gauge.
Symmetries, Ward-Takahashi and Slavnov-Taylors identities. The case of QED and QCD. Anomalies in QFT. Axial and chiral anomalies. ABJ anomaly: the triangle disgram. Fujikawa's method. Anomalies in gauge theories. BRST approach to anomalies. Wess-Zumino consistency condition. Descent equations. 't Hooft anomalies. 't Hooft anomaly matching condition.
Dira monopole. Solitons in 2D. Dirac-Polyakov monopole in Georgi-Glashow model.
Instantons in gauge theories and theta-vacua.

Prerequisites

General Relativity, Theoretical Physics I,II, Quantum Field Theory I

Teaching form

Frontal lectures and class tutorials. There will be no remote teaching.

Textbook and teaching resource

M.E. Peskin, D.V. Schroeder, An introduction to Quantum Field Theory P. Ramond, Field Theory : A Modern Primer, 2nd Edition
M. Srednicki, Quantum Field Theory
T-P. Cheng and L-F. Li, Gauge Theory of Elementary Particle Physics D. Anselmi, Renormalizazion
S. Weinberg, The Quantum Theory of Fields I, II
R. Rajaraman, Solitons and Instantons

Semester

Second semester

Assessment method

Oral exam preceded by a short exercise to be solved in presence.
The final evaluation will take into account the level of comprehension of all the topics introduced in the course, the level of computational skills in QFT acquired, as well as scientific language skills and clarity of the answers.

Office hours

By appointment, sending an e-mail to silvia.penati@unimib.it

Sustainable Development Goals

QUALITY EDUCATION