Finite-Temperature Field Theory

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Teaching staff

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Reception hours: Wednesday from 10:00 to 12:00 and Thursday from 15:00 to 17:00

Program of the course:

This course provides an introduction to perturbative thermal quantum field theory, focusing on systems in equilibrium at finite temperatures and chemical potentials. We will primarily utilize the functional integral approach to explore these systems. The course covers essential tools such as functional integration, Matsubara summation, and perturbative techniques. Key theoretical concepts like spontaneous symmetry breaking and its restoration at high temperatures will also be discussed. By the end of the course, students will have basis of computational techniques used in thermal field theory, with an emphasis on perturbative methods. They will be able to compute partition functions for free scalar, fermionic, and gauge field theories using path integral and analyze the thermodynamic properties and propagators of quantum fields via the Matsubara formalism.

Plan of the course

- Quantum Statistical Mechanics: Path integral formulation of quantum statistical mechanics. The Matsubara (imaginary-time) propagator. Frequency summation techniques
- Scalar Fields at Finite Temperature: Frequency sums for bosonic Matsubara frequencies. Pressure calculation of a scalar field. Complex non-interacting scalar fields. Conserved charge and chemical potential. Real-time formalism in thermal field theory. Interactions and diagrammatic techniques. Perturbative expansions

- Non-interacting Fermion Fields: Grassmann algebra and antiperiodicity for fermion fields at finite temperature. Fermionic Lagrangian and conserved charge. Partition functions for fermions. Frequency summation for fermionic Matsubara frequencies. Thermodynamic potential for fermion systems.
- Gauge Fields in Thermal Quantum Field Theory: Lagrangians for QED and QCD at finite temperature. Path integral formulation of the partition function for gauge fields
- Linear Response Theory: Plasma oscillations and their interpretation in the context of thermal field theory. Transport coefficients and their computation

Bibliography:

- J. I. Kapusta and C. Gale, Finite Temperature Field Theory: Principles and Applications, Cambridge University Press (2023).
- M. L. Bellac, Thermal Field Theory, Cambridge University Press (2011).
- Scientific papers will be provided during the lectures.