Quantum Field Theory (M24)

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Quantum Field Theory is a marriage of quantum mechanics and special relativity which provides the mathematical framework for describing the interactions of elementary particles. This first Quantum Field Theory course introduces the basic types of fields which play an important role in high energy physics: scalars, (Dirac) spinors, and gauge fields. The relativistic covariance and symmetry properties of these fields are discussed using the language of Lagrangians and Noether's theorem. The quantisation of free fields is developed using Hamiltonian methods in terms of operators which create and annihilate particles and anti-particles. The Fock space of quantum physical states and the associated realisation of particle statistics is described. Interacting field theory is developed next using Dyson's formula for the scattering amplitude. Perturbation theory is formulated by applying Wick's theorem and Feynman diagrams are introduced as an efficient way of organising the resulting calculations. Physically measurable quantities such as decay rates and cross-sections are defined. Spinors and the Dirac equation are explored in detail, along with parity and chirality. Fermionic quantisation is developed, along with Feynman rules and Feynman propagators for fermions. We review the relativistic formulation of Maxwell's equations formulating a corresponding action principle. The significance of gauge invariance is discussed. Lorentz gauge quantisation of the electromagnetic field is accomplished by imposing the Gupta-Bleuler condition. Finally, quantum electrodynamics (QED) is developed. Interactions between photons and charged matter are introduced via the principal of minimal coupling. We discuss the calculation of tree-level scattering amplitudes in QED.

Prerequisites

You will need to be comfortable with the Lagrangian and Hamiltonian formulations of classical mechanics and with special relativity. You will also need to have taken an advanced course on quantum mechanics including Dirac's "bra/ket" notation. A basic knowledge of group theory is also very useful for this course.

Literature

1. D. Tong, *Lectures on Quantum Field Theory* `http://www.damtp.cam.ac.uk/user/tong/qft.html`. These printed lecture notes have a large overlap with the current course.

2. T. Lancaster and S.J. Blundell, *Quantum field theory for the gifted amateur*, Oxford University Press (2015) is an introductory text that Part III students have found useful.

3. M.E. Peskin and D.V. Schroeder, *An Introduction to Quantum Field Theory*, Addison-Wesley (1996) is a classic, and also covers aspects of the Standard Model.

4. A. Zee, *Quantum Field Theory in a Nutshell*, Princeton University Press, (2010) gives a modern take with a lot of physical intuition, possibly taking the subject into topics more theory-specialised and advanced than the references above.

Additional support

Four examples sheets will be provided and four associated examples classes will be given. There will be a weekly office hour in Michaelmas term. One revision class will be given in Easter term.