

A three-module course on quantum field theory

I. Renormalization of ϕ^4 , ϕ^3 and QED

- UV divergent amplitudes at one loop of ϕ^4 and ϕ^3
- QED gauge invariance
 - Wilson lines
- Renormalization of QED
 - quantization of the photon and Faddeev-Popov ghosts
 - Ward identities
 - one-loop UV divergent amplitudes and counterterms
 - effective charge and electron-photon vertex
 - electron anomalous magnetic moment
- Wilson's picture of renormalization
- Massless theories
- Callan-Symanzik (CS) equation and β and γ functions for
 - ϕ^4 and ϕ^3
 - massless QED
- resummation of leading logs
- running of the coupling constant
 - asymptotic freedom of ϕ^3
- fixed points and anomalous dimensions
- local operators
- mass operators and Wilson-Fischer fixed point

Prerequisites to the first module

- canonical quantization
- path-integral quantization
- Feynman rules
- LSZ reduction

II. Parton model and QCD

☛ Parton model

- Deep Inelastic Scattering (DIS)
 - parton distributions
 - sum rules
- charged and neutral currents
 - helicity amplitudes

☛ QCD

- Colour algebra
- Gauge symmetry
 - connections, comparators, Wilson loops
- Renormalization of the Yang-Mills theories
 - Ward identities and unitarity: Feynman ghosts
 - quantization of the gluon and Faddeev-Popov ghosts
 - one loop UV divergent amplitudes and counterterms
 - the β function
 - * running of the coupling constant
 - * asymptotic freedom
- Chiral symmetry breaking
 - Pions as Goldstone bosons
 - chiral perturbation theory
- Heavy quark effective symmetry

☛ Perturbative QCD

- $e^+e^- \rightarrow$ hadrons
 - the R ratio
 - Callan-Symanzik equation
 - final states
 - * infrared and collinear divergences
 - Bloch-Nordsieck theorem
 - KLN theorem
 - * eikonal rules and jets
 - * event shape variables
- Drell-Yan scattering
- hadron-hadron collisions
- modern techniques for the computation of scattering amplitudes
 - colour decomposition
 - helicity amplitudes
- DIS
 - Altarelli-Parisi evolution
 - Parton distributions
- Renormalization of the quark mass
- Renormalization of weak decays
- OPE
 - $e^+e^- \rightarrow$ hadrons
 - DIS

III. Symmetry breaking in QFT

- global symmetries
- spontaneous global symmetry breaking
 - Goldstone theorem
 - chiral symmetry breaking
 - * low-energy QCD
 - * linear sigma models
- gauge symmetries
- spontaneous gauge symmetry breaking
 - Higgs mechanism
 - Standard Model
- custodial symmetry
- renormalization of spontaneously broken gauge symmetries