Quantum field theory - NPAC
M. Cacciari and S. Descotes-Genon

QFT in a nutshell [M. Cacciari]

A1. Recap of special relativity
- Change of frame, four vectors, boosts
- Relativistic kinematics
- Decay in two, three bodies
- Two-body reactions, phase space and flux, cross section

A2. Introduction to spin 0, 1/2, 1 particles
- Klein-Gordon lagrangian
- Notion of spin, helicity, polarisation
- Dirac and Electromagnetism lagrangians

A3. Dirac equation
- Dirac equation and its solutions
- Diracology
- Illustration: g-2 (first order)

A4. QED
- Gauge invariance, covariant derivative
- Coupling of photon to fermions
- Feynman rules
- First applications: e.m. potential

A5. e+ e- -> mu+ mu-
- Computation with trace identities
- Angular analysis
- Helicity analysis
- Non-relativistic and ultrarelativistic limits
- Crossing symmetry

A6. Electron-photon interaction
- Compton scattering
- Bhabha scattering
- Soft bremsstrahlung
- Infrared and collinear divergencies

A7. Vacuum polarisation 1
- Notion of self-energy
- One-loop computation
- Notion of regularisation
- Implementations: dimensional regularisation, alternatives

A8. Vacuum polarisation 2
- Renormalisation
- Renormalisation group equation
- Consequences for coupling constant

A9. QCD

Elements of group theory and gauge invariance
QCD lagrangian, Feynman rules, colour algebra
R(e+e- -> hadrons) at tree level
Vacuum polarisation for gluons, running of alpha_s
Deep Inelastic scattering, Drell-Yan, PDFs
Notion of ghosts

A10. Standard Model

Basic elements
Lagrangian
Feynman rules for weak bosons and Higgs
Illustrations : gg -> top loop -> H

Fundations of QFT [S. Descotes-Genon]

B1. Lagrangian and symmetries

QFT view point
Lagrangian, action, Euler-Lagrange equations
Continuous symmetries and discrete symmetries
Noether theorem

B2. Spin 0 particles

Quantisation of real and complex Klein Gordon fields
Propagator
Particle creation from a classical source
Notion of antiparticle

B3. Spin 1/2 particles

Dirac equation
Quantisation and spin-statistics theorem
Dirac propagator
Discrete symmetries of Dirac theory

B4. Interacting fields

S-matrix and perturbation theory
Wick theorem
Feynman diagrams : principle and combinatorics
Combinatorics of Feynman diagrams
Illustration with (g-2)_muon

B5. Path integral and functional methods

Path integral in quantum mechanics
Functional quantisation of scalar fields
Symmetries in functional formalism

B6. Renormalisation

Concepts
Ultraviolet divergences and power counting
Renormalisation group equations
Structure of QED at one loop and role of symmetries
Renormalisability and effective theories

B7. Symmetry breaking

Position of the problem in the Standard Model
Explicit and spontaneous symmetry breaking
Global symmetry breaking: Goldstone theorem and low-energy QCD
Spontaneous symmetry breaking: Higgs mechanism abelian example

B8. Standard Model (1)

Electroweak symmetry breaking
Higgs field and its potential
Gauge boson masses and custodial symmetry

B9. Standard Model (2)

Coupling to fermions
CKM and PMNS matrices
Symmetries of the Standard Model

B10. Formal developments

Standard Model at one loop
Unitarity, optical theorem, ghosts
Anomalies
Unification

Bibliography

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