Questions on the lectures "Introduction to QCD"

A. Banfi and A. Lazopoulos

July 11, 2010

Questions are classified in three categories: easy (E), medium (M) and difficult (D).

Lecture 1

- E: What was historically the main experimental evidence for the number of color degrees of freedom?
- M: Describe the concept of Bjorken Scaling and its importance.
- D: Describe a method to measure the charge of the quarks within DIS.

Lecture 2

- E: Derive the QCD classical Lagrangian
- M: Derive how the field strength transforms under a finite and infinitesimal gauge transformation. To which representation of SU(N_c) does $F_{\mu\nu}$ belong?
- D: Derive $C_F = (N_c^2 - 1)/(2N_c)$

Lecture 3

- E: What are the QCD Feynman rules?
- M: Derive the ghost Lagrangian in a covariant gauge
- D: What is the role of ghosts in unitarity of QCD?

Lecture 4

- E: Which types of diagrams are UV divergent in QCD?
- M: Sketch the renormalization procedure for the gluon propagator.

- D: Describe the concept of renormalization scheme dependence and give the definition of the MS bar scheme.

Lecture 5

- E: For each propagator and vertex that are UV divergent in QCD, write the renormalization constants in terms of renormalization constants for the fields, coupling and mass. Which particular diagrams contribute for each at NLO?
- M: Derive the renormalization constant for the ghost propagator.
- D: Discuss the Slavnov-Taylor identities at NLO and at all orders.

Lecture 6

- E: Derive the beta function in MS scheme
- M: Derive and solve the RG equation for Feynman amplitudes
- D: How can one use RG equations to fix renormalisation scale in physical observables?

Lecture 7

- E: What is the singularity structure of the $e^+e^- \to X$ hadrons at NLO?
- M: Derive the eikonal approximation for the real emission amplitude.
- M: Show how do IR singularities appear within D-dimensional regularization?
- D: Describe the concept of Infrared Safety.

Lecture 8

- E: How are the structure functions defined in DIS?
- M: Derive the Callan-Gross relation in the naive parton model.
- D: Why don't the IR divergences cancel at the partonic level in DIS?
- D: Derive the Altarelli - Parisi splitting function for quark $\to$ quark (the fast way).

Lecture 9

- E: How does the initial state collinear divergence gets absorbed in the renormalized PDFs?
- M: Derive the DGLAP equations.
- D: Solve the DGLAP equations for the NS case of a quark PDF.

Lecture 10

- E: Derive the total cross section for lepton pair production in the parton model. How this result is extended to W production?
- M: Discuss the main features of the rapidity distribution of Z and W bosons at the Tevatron and at the LHC D: Describe the NLO calculation of the Drell-Yan total cross section and perform the calculation in full detail for a term at your choice contributing to the real emission part.

Lecture 11

- E: What is meant by factorisation of QCD cross sections?
- M: Compute the one-loop virtual correction to the DIS process in the soft or collinear approximation
- D: Derive and discuss Landau equations for the one-loop virtual corrections to DIS

Lecture 12

- E: Draw the leading regions for e+e-, DIS and DY total cross sections in a covariant gauge
- M: Using the KLN theorem, find as many as possible infrared and collinear safe observables
- D: Sketch the proof of factorisation for DIS and DY total cross sections

Lecture 13

- E: Describe schematically the stages of showering and hadronization, and the concept of underlying event.
- M: Describe the concept of ordering in parton showers.
- D: What is the Sudakov form factor?