Lecture notes Particle Physics II

Quantum Chromo Dynamics

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QCD in Eight Lectures

1. Review of SU(2) and SU(3) symmetry.
2. Lagrangian formalism and U(1) local gauge invariance.
3. The SU(2) (Yang-Mills) and SU(3) (QCD) invariant Lagrangian.
4. From the QCD Lagrangian to Feynman rules and colour factors.
5. The running coupling constant and asymptotic freedom in QCD.
6. Infrared and collinear singularities.
7. The structure of the proton.
8. The QCD improved parton model and DGLAP evolution.

The lecture notes can be found on

`http://www.nikhef.nl/user/h24/qcdcourse`

Background material

The lectures are based on the following books:

Griffiths D. Griffiths, *Introduction to Elementary Particles*, Second Revised Edition, WILEY-VCH, (2008);

H&M F. Halzen and A.D. Martin, *Quarks and Leptons*, John Wiley & Sons, (1984).

You will need these books to supplement the lecture notes, and to successfully complete the exercises.

Some reference is also made to

PP-I W. Hulsbergen and M. Merk, *Lecture notes Particle Physics I.*

The following references were used in the preparation of these notes:

A&H I.J.R. Aitchison and A.J.G. Hey, *Gauge Theories in Particle Physics*, IOP Publishing Ltd, Volumes I and II, (2003);

DKS G. Dissertori, I. Knowles and M. Schmelling, *Quantum Chromodynamics*, Oxford University Press, (2003);

ESW R.K. Ellis, W.J. Stirling and B.R. Webber, *QCD and Collider Physics*, Cambridge Univeristy Press, (1996);

CTEQ CTEQ Collab. G. Sterman et al., *Handbook of Perturbative QCD*, Version 1.0 (2000), obtainable from `http://www.phys.psu.edu/~cteq`;

Soper D.E. Soper, *Basics of QCD Perturbation Theory*, hep-ph/9702203, (1997);

deWit B. de Wit and J. Smith, *Field Theory in Particle Physics*, Volume 1, North Holland, (1986);

Zee A. Zee, *Quantum Field Theory in a Nutshell*, Second Edition, Princeton University Press, (2010);

Ramond P. Ramond, *Group Theory*, Cambridge University Press, (2010);

Veltman M. Veltman, B. de Wit and G. 't Hooft, *Lie Groups in Physics*, Lecture notes, `http://www.staff.science.uu.nl/~hooft101/lectures/lieg07.pdf`;

Schiff L.I. Schiff, *Quantum Mechanics*, Third Edition, McGraw-Hill, (1968);

Jackson J.D. Jackson, *Classical Electrodynamics*, Second Edition, John Wiley, (1975).

Grading

You may hand-in exercises which will then be graded as follows:

Good	$\rightarrow$	score = 1.0
Reasonable	$\rightarrow$	0.6
Bad	$\rightarrow$	0.3
Not made	$\rightarrow$	0.0

You can **only** hand-in those (sub-)exercises that have a weight factor given in square brackets. The exercises marked with a [$\times$] will help you to better understand the material but you can **not** hand them in and gain bonus points with them. At the end of the course your final score is calculated as the weighted average of the individual scores. Bonus points are then added to the grade of your exam in proportion to your exercise score. As an example, we list below the bonus for an exercise score of 0.8:

Exam grade	0 – 7	8	9	10
Bonus	1.0	0.8	0.4	0

Note that the bonus is less for high exam grades, to avoid that the total grade will exceed the maximum of 10 points.[1]

Because we cannot handle a pile-up of exercises at the end of the course, we make the rule that you cannot hand-in more than 5 exercises at a time. At the day of the exam you can bring your last five exercises.

The exam is 'open book' so that you may consult the lecture notes and the books of Griffiths, Halzen & Martin and Aitchison & Hey, but not the worked-out exercises or any other material.

[1] The bonus is calculated from $B = E \times \min(5 - 0.5\,T, 1.25)$, where $0 \leq E \leq 1$ is your exercise score, and $0 \leq T \leq 10$ is your exam grade.