

Fys5120 (Fys9120 for phd.), Spring 2013.

Content and schedule.

Below MS refers to the text-book of Madl and Shaw (used in Fys4170), and PS refers to the text-book of Peskin and Schroeder.

There has normally been lectures two times a week; wednesday 14.15-16 and thursday 10.15-12.

- The first five weeks (weeks number 3-7, 15th of january until 14th of february) I talked about radiative corrections within QED. This includes:

Regularization of divergent loop diagrams using (large) cut-offs Λ or *dimensional regularization*. The concept of *Renormalization of mass, electron and photon fields, and electric charge* was also introduced.

These subjects will be found in PS at pages: 175-208, 216-222,230-257; or eventually also in MS at the pages: 161-216,330-336. Especially, we considered the three divergent loop diagrams:

- 1) The electron self-energy diagram given by $\Sigma(p)$; see pages 216-222 in PS and pages 172-176 and 193-195 in MS.
- 2) The photon self energy given by the Vacuum polarization tensor $\Pi^{\mu\nu}$; see pages 244-252 in PS and 167-171 and pages 211-214 in MS.
- 3) The vertex correction diagram given by $\Delta\Gamma^\mu(p', p)$; (-including the (g-2) for the electron.) see pages 189-196 in PS and in MS at pages 178-180 and 214-216.

I have also talked about infrared effects (“Sudakov logarithms”) in soft photon bremsstrahlung; pages 176-184 and 199-208 in PS, and 155-158 and 191-193 in MS. (Only the one-photon case was covered in the lectures).

I also mentioned (first week of febr.) *Ward-identities*, pp 238-244 (for inst the relation between the self energy Σ and the vertex correction $\Delta\Gamma^\mu$), pp 238-244 in MS and page 181 in MS (-again only the one-photon case was covered)

I talked about *The optical theorem* and *Imaginary parts* of loop amplitudes; (pages 230-236 in PS) and the Breit-Wigner form of propagators for unstable particles (pages 236-237 in PS and 439-440 in MS).

- The week number 8 (20th and 21th of february) I started to talk about the *Renormalization Group Equations* (RGE),- specified to the *Callan-Symanzik* equations;- exemplified within *mass-less ϕ^4 -theory*. These subjects might be found in PS at pages 394 -437;- but I have given a more simplified presentation in the lectures. (-a scanned version of concentrate of lecture notes is given).

Week number 9 (and first two days of week number 10) we had Mid-term exam.

The week number 10 (wednesday 6th and thursday 7th of march) I continued lectures on *RGE*.

The next topic was *RGE* for QCD (a simplified version for mass-less quarks) which was the subject in week 11 (wednesday 13th and thursday the 14th of march)

RGE for QED and QCD is treated at pages 336-343 and 351-352 in MS, and in PS at pages 551-554 and 599-615.

Then (week 12) I talked about the axial anomaly (Only a simplified treatment was given. A more extended analysis is given at the pages 659-664 and 672-676 in PS).

- Week number 13 is the easter week with no lectures
- The thursdays 4 and 11 of april I started to talk about some topics of electroweak interactions:
 - *) The “unphysical” Higgs couplings when using Feynman gauge of the W-propagator (p 749 in PS),
 - *) $K^0 \rightarrow \mu^+ \mu^-$, and $K^0 \leftrightarrow \overline{K^0}$ at quark level (pp 719-727 in PS), and QCD corrections for non-leptonic decays ($K \rightarrow \pi \pi$, say. See pages 605-612).
 - *) Week number 16 (i.e. 17th and 18th of april) there were no lectures because I was on a conference in particle physics. Instead some problems were given (see “Problems for FYS5120-April 2013” at the web-page). Wednesday the 24th there was comments on the given problems (sketching possible solutions), and then further discussion on Non-leptonic decays.
 - *) Then I gave a simplified description on *deep inelastic scattering* (The process(es) $ep \rightarrow eX$, where X is “any possible hadronic state” consistent with relevant conservation laws. (pp 475-480, 555-563, 623-627)
- Thursday the 2. of may I talked about path integrals in quantum mechanics (I gave a simplified description. More extensive descriptions of this can be found in the notes of Fys 4110 (pp20-24) and pp 275-282 of PS).

Wednesday the 8. of may I talked about Path Integrals for Fields, and on Grassman variables (See PS, pp 289-292, 299-302.

Wednesday the 15th and thursday the 16th of may I talked about gauge fixing in QED (pp 294-297 in PS), QCD (512-515) and the abelian Higgs (toy-)model (732-735) in terms of the Fadeev-Popov method. (Also, in MS; a more extensive treatment of functional methods, path integrals are described at the pages 256-319)

- *) Wednesday the 22. of may I shortly talked (the first hour) about SSB (breakdown of chiral symmetry) in QCD (pp 667-670 in PS).
*) I mentioned shortly “Thermal Quantum Field Theory”, which is more thoroughly described in the course Fys 9180.
- Second hour 22.th of may, and the two hours thursday 23. of may was repetition.
- At last, I have written 32 handwritten pages summing up the course.

Jan Olav Eeg