Warsaw, 20 May 2005 r.

Theory of elementary particles 2004/2005

Problems for the oral exam

1. Discuss the construction of field theory with Abelian gauge symmetry
2. Demonstrate the gauge invariance of the kinetic term in theories with non-Abelian gauge symmetry
3. Discuss the basic steps of canonical quantization of the field theory
4. Explain the normal ordering of the operators, and its necessity in quantizing canonically the field theory
5. Discuss the perturbation theory and the S matrix.
6. Formulate the Wick theorem and illustrate its application in a few examples
7. Discuss the canonical quantization of the fermion field.
8. Discuss on an example of your choice the derivation of the S matrix element in the lowest order of perturbation theory in Quantum Electrodynamics (QED).
9. Discuss concepts of cross sections and decay widths
10. Discuss the Fermi theory of weak interactions and explain its difficulties (unitarity, renormalization)
11. Discuss the spontaneous breaking of global gauge symmetry (Goldstone model)
12. Discuss the spontaneous breaking of local gauge symmetry (Higgs model)
13. Discuss the gauge symmetry in the Standard Model (SM).
14. Discuss fermion interactions in The SM.

15. Derive the $m_W/m_Z = \cos\theta_W$ relation in the SM.

16. Discuss the parity (P) and charge conjugation (C) transformations.

17. Derive the CP invariance of QED.

18. Derive the Cabibbo-Kobayashi-Maskawa mass matrix.

19. Discuss the CP properties of the SM.

20. Discuss the Dirac and Majorana mass terms.

21. Neutrino oscillations.

22. How the neutrino masses are measured/

23. Discuss weak decays of quarks and mesons.

24. The GIM mechanism (Glashow-Iliopoulos-Maiani) and flavor changing neutral currents.

25. Discuss the concepts of (strong) isospin and strangeness.

26. Flavor SU(3) group, its reprezentations, Yang diagrams, classifications of mesons and baryons in SU(3)

27. Quark model, mass relations for baryons

28. Discuss the elastic scattering $e\mu \to e\mu$, compare it to the scattering on a spinless target.

29. Elastic scattering $ep \to ep$, proton formfactors.

30. Deep inelastic scattering (DIS) $eN \to eX$, structure functions F_1, F_2, Bjorken scaling.

31. DIS $\nu N \to eX$, structure functions F_1, F_2, F_3

32. Parton model, Callan-Gross relation, quarks as partons, quark and gluon distributions in a nucleon.

33. Discuss arguments for antiquarks in a nucleon.

34. Sum rules: Gottftried, Llewellyn-Smith, momentum.

35. Idea of the renormalization

36. Eenormalization group equations

37. Beta function for QED and for nonabelian SU(N) gauge theories
38. Running coupling constatns, fixed points in IR and UV
39. Optical theorem, Cutkosky cutting rules
40. QCD corrections to $\sigma(e^+e^- \to hadrony)$, and to deep inelastic scattering
41. Grand unification, SU(5), SO(10), proton decay
42. Hierarchy problem of the Standard Model
43. Idea of the supersymmety
44. Struture of the MSSM