FYST17: examination questions (sample)

(6 topics with 3 questions, giving 2 pts each)

1. **Basic concepts**
   a) Specify all the known quark and lepton flavours and generations; write values of all quantum numbers of quarks and leptons.
   b) Describe connection between coupling constants and probabilities of processes. Bhabha scattering is the elastic process in which electron and positron exchange a photon; and Møller scattering is an electron-electron elastic scattering via a photon – compare relative probabilities of the two processes in the lowest order.
   c) Feynman diagrams: define basic rules, explain the difference between virtual and real processes, draw examples of 8 basic processes involving electron, positron and photon.

2. **Leptons, quarks and hadrons**
   a) Categorize hadrons into two groups according to their quark structure; write possible values of all their quantum numbers that arise from quark constituents.
   b) Which of the following weak processes are allowed, and which – forbidden? Explain why, draw valid Feynman diagrams.
   - $\nu_e + p \rightarrow e^+ + n$
   - $\Sigma^+ \rightarrow p + \pi^0$
   - $\Lambda \rightarrow K^+ + e^- + \overline{\nu}_e$
   - $\tau^- \rightarrow \pi^- + \nu_\tau$
   - $K^0 \rightarrow \pi^- + \pi^+$

   c) Up- and down-quarks possess a specific quantum number – the isospin. Describe how does this give rise to isomultiplets (and isosinglets) of hadrons.

3. **Experimental methods**
   a) Explain purposes of tracking detectors and calorimeters. How these differences affect relative placement of such detectors in a collider experiment?
   b) Describe the phenomenon of synchrotron radiation and its implications on high-energy physiucs accelerators. Estimate the magnetic field strength (in Tesla) needed to accelerate protons to 7 TeV in LHC (bend radius ~2.8 km).
   c) Describe some detector installations used to measure neutrino oscillations. Which phenomenon of particle interaction with matter is most commonly used nowadays to detect neutrino interactions?

4. **Symmetries**
   a) A system of particles undergoes an operation which changes coordinates of a system. In which case the operation is said to be a symmetry operation? List some key known symmetries.
   b) How parities *P* of quarks and leptons are defined? How to express intrinsic parities of mesons and baryons via parities of constituent quarks?
   c) Draw the Feynman diagram for $B^0 - \overline{B}^0$ mixing (hint: $B^0 = (d\overline{b})$)

Please turn over

5. Strong interactions

a) Explain the principle of color confinement. Write down color states that are possible for quarks, gluons and hadrons.

b) The scattering of an electron on a proton can proceed through elastic and deep-inelastic channels. Draw the lowest order Feynman diagrams for the two cases. How can one distinguish between them experimentally?

c) In electron-positron annihilation experiments at high energies, observed particles are clustered to jets. Why the final particles distribution is not isotropic, and what is the origin of the observed jets?

6. Weak interactions and new physics

a) What are weak gauge bosons? Describe their properties and draw Feynman diagrams for basic couplings of those bosons to quarks and leptons.

b) Describe the main features of Supersymmetry. Has the theory been experimentally verified? What effect can Supersymmetry have on the Grand Unification Theory?

c) Explain the concept of quark mixing. Consider the case of the two first generations only (u, d, c, s). Why do charm quarks almost always decay into strange quarks?