Elementary Particle Physics: Assignment # 1

Due 1/31/17 11:30 pm

1 Using the quarks of the first and second generation construct a table with all possible baryon species (remember baryons have $B = 1$ and Q must be entire) and write their quantum numbers (Q,U,D,S,C). Search which of these baryons are listed in the particle data group weg page http://pdg.lbl.gov/ and give their names.

2 For the following reactions write the quantum numbers Q,L,B,L_α ($\alpha = e, \mu, \tau$) , S (strangeness), C (charm) for all the states and use the conservation of quantum numbers described in class to discuss which processes are forbidden and which are allowed by some of the three types of interactions: strong, electromagnetic or weak and why. For processes allowed by weak interactions only, discuss which ones would be forbidden if neutrinos were massless, and which ones we do not know yet if they are allowed or not.

(a) $\tau^- \to \mu^- e^+ e^-$ (b) $p \to e^+ \pi^0$ (c) $n\, n \to p\, p\, e^-\, e^-$
(d) $n\, p \to p\, n\, \pi^+$ (e) $\tau^+\tau^- \to \nu_\mu\, \bar{\nu}_\mu$ (f) $\Lambda_c^+ \to \Sigma^+\pi^0$

3 During almost 2 decades the accelerator LEP at CERN in Switzerland collided beams of electrons and positrons with the aim of studying in detail our understanding of the particle interactions and to test the Standard Model. In the first phase (called LEPI) the energy of the beams was tunned to produce a large amount of Z^0 bosons at rest to obtain a precise determination of its mass and its decay properties. Answer the following questions

3.1 We know now the mass of the Z^0 (search for it in Particle Data Group webpage). What was the energy of the colliding beams to produce the Z^0's at rest?

3.2 Z^0 quickly decays, about 6% of the times in $\tau^+\tau^-$. How far do the τ travel before they also decay? (look for τ mass and lifetime in PDG webpage).

3.3 A theorist has predicted that once in 10^4 times the Z^0 should decay into a pair of "exotic" identical neutral leptons with mass $M = 30$ GeV which should decay into charged leptons. The experiment has produced millions of Z^0 and did not find any unusual event. What can they tell to the theorist about the lifetime of this exotic particle? (hint: the event of a Z^0 decaying so rarely into these heavy neutral leptons can only be "seen" if the neutral lepton decays inside the detector. Assume that the maximum distance from the interaction point to the edge of the detector is 10 m.)