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PHZ4390
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Homework 4

Due Monday, Sep. 23, 2013

1. Answer the following questions. The "elementary fermions" mentioned are leptons and quarks. You don't have to list antifermions.
   a. (3 pts) List all elementary fermions that can participate in E&M interactions.
   b. (3 pts) List all elementary fermions that can participate in strong interactions.
   c. (4 pts) List all elementary fermions that can participate in weak interactions.
2. (15 pts) Indicate which if any conservation laws would be violated in the following reactions. For lepton number, see the discussion in Chapter 2 of M&S.

Reaction	Angular momentum	Lepton number	Baryon number	Energy
$\mu^- \to e^- \nu_e$				
$n \to p e^- \overline{\nu}_e$				
$n \to \pi^+ e^- \gamma$				
$\pi^- \to \tau^- \gamma$				
$n \to \overline{p} e^+ \nu_e$				
$\Sigma^- \to \overline{p} \gamma$				
$\mu^- \to e^- \gamma$				
$n \to \nu_\mu \gamma$				
$n \to \pi^+ e^- \overline{\nu}_e$				
$\Lambda \to p K^-$				
$\Sigma^{*+} \to \Lambda \pi^+$				

3. These questions apply to the light spin 1/2 baryons.
   a. (2 pts) Write the quark content of the 8 light spin 1/2 baryons.
   b. (2 pts) Which baryons have the same quark content? Why are the masses so different?
   c. (2 pts) Why is the lifetime of the Σ^0 so different than that of Σ^+ and Σ^-?
   d. (2 pts) Does the Σ^0 decay into $p\pi^-$ or $n\pi^0$? Have they been seen?
   e. (2 pts) Why is the neutron lifetime so long?

4. Answer the following questions for the spin 3/2 baryons: Δ, Σ^*, Ξ^* and Ω^-. Use the PDG (Summary Tables of Baryons) as needed.
    a. (2 pt) The particles are arranged in multiplets, as shown in the note on light hadrons. Why do the masses change from level to level?
    b. (2 pts) Give one typical decay channel for each baryon (one per multiplet).
    c. (2 pts) Using the quark structure of Δ^{++} and Ω^- baryons, draw Feynman diagrams for these decay modes.
    d. (2 pts) Why is the lifetime of the Ω^- so different from the other spin 3/2 baryons?
    e. (2 pt bonus) What Ω^- property would have to change (and by how much) to make its lifetime comparable to that of the other spin 3/2 baryons?
5. Use the Summary Tables of Baryons and Summary Tables of Mesons from the PDG.
    a. (4 pts) What is the lightest charm baryon and its mass and lifetime (MeV, psec)? What is the lightest charm meson and its mass and lifetime (MeV, psec)?
    b. (3 pts) What is the lightest bottom baryon and its mass and lifetime (MeV, psec)? What is the lightest bottom meson and its mass and lifetime (MeV, psec)?
    c. (3 pts) Why would you expect the lightest charm baryon and lightest charm meson to always decay weakly?
6. Use the Summary Tables of Baryons from the PDG online.
    a. (2 pts) Give the quark content of the lightest Σ_c^0, Σ_c^+ and Σ_c^{++} baryons (these form a multiplet of mass ~2455 MeV). Each has a single charm quark.
    b. (2 pts) Let Δ be the electromagnetic contribution to the mass between two quarks if they both had charge = e. Write the mass of each baryon in terms of the quark masses and Δ, similar to what we did in class (described in note on light hadrons).
    c. (2 pts bonus) Use the mass splittings, $m_{\Sigma_c^{++}} - m_{\Sigma_c^0}$ and $m_{\Sigma_c^+} - m_{\Sigma_c^0}$ shown in the PDG table (the splittings are displayed separate from the masses because they are known more accurately) to estimate $m_d - m_u$ and Δ. Are these values consistent with what we learned from the (n, p), ($\Sigma^-, \Sigma^0, \Sigma^+$) and ($\Xi^-, \Xi^0$) multiplets that we did in class?
    d. (2 pts bonus) Consider the two members of the Ξ_c multiplet, Ξ_c^0 and Ξ_c^+. The mass splitting is shown under the Ξ_c^0. What is your prediction of the splitting from (c)?