Physics 125 Final

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Open book, notes. Express answers in symbolic form first, and then, when asked, in numerical form. Give numbers to two significant figures.

1. (32 pts) Examine the following processes, and state for each one whether it is *possible* or *impossible*, according to the Standard Model (which does not include GUTs, with their potential violation of the conservation of lepton number and baryon number). If the process is possible, state which interaction is resonsible and most important - strong, electromagnetic, or weak, and draw a Feynman diagram. If the process is weak, and involves quarks, indicate the strength of the amplitude in terms of G_F and CKM matrix elements. If the process is impossible, cite all conservation laws that prevent it from occurring.

   (a) $\Sigma^0 \to \Lambda\gamma$

   (b) $\Sigma^- \to n\pi^-$

   (c) $\pi^0 \to \mu^+ e^-$

   (d) $\rho^0 \to \pi^+\pi^-$

   (e) $D^0 \to \overline{K}^0\pi^0$

   (f) $p \to \pi^0 e^+ \nu_e$

   (g) $\tau^- \to D^- \nu_\tau$

   (h) $\Sigma^+ n \to \Sigma^- p$

2. (20 pts) A D^0 meson (mass $m_0c^2 = 1865\,\mathrm{MeV}$) decays into three particles: one ϕ meson (mass $m_1c^2 = 1020\,\mathrm{MeV}$), one η meson (mass $m_2c^2 = 547\,\mathrm{MeV}$), and one π^0 meson (mass $m_3 = 135\,\mathrm{MeV}$).

   Work this problem in the rest frame of the D^0. In that frame, the D^0 decays to a particular final state in which the η ends up exactly at rest. For this final state, what are the total energies (including energy from the mass) of the ϕ (denoted E_1), and of the π^0 (denoted E_3)?

   There is no need to draw any Feynman diagrams for this problem.

3. (20 pts) Suppose you had particle #1 of spin 2, in a state with $S_z = -1 \times \hbar$, and also particle #2 of spin 3/2, in a state with $S_z = +1/2 \times \hbar$. If you measured the *total* angular momentum of this system, given that the *orbital* angular momentum is zero, what values would you get, and what is the probability of each?

(More problems... OVER)

4. (30 pts) Use the ABC theory of Chapter 6 to calculate both $d\sigma/d\Omega$ and the total cross section σ for $A + A \to B + B$, in the CM frame. Assume that $m_C c \gg$any of the momenta of the particles, so that the momenta can be neglected where appropriate. Express your answer in terms of $E = \sqrt{s} \times c$ (where $s = (p_1 + p_2) \cdot (p_1 + p_2)$), the masses, and other fundamental constants.

5. (20 pts) Use the ABC theory of Chapter 6 to draw all $\mathrm{O}(g^3)$ Feynman diagrams for the scattering process $A + B \to B + B + C$. You need not evaluate either the amplitude or the cross section.

6. (20 pts) In nuclear reactors, neutron decays emit electron anti-neutrinos with a typical energy of 0.6 MeV. Suppose these electron antineutrinos mix with a second antineutrino that is undetectable. The mass difference between the two eigenstates is $\Delta M^2 c^4 = 10^{-4}\,\mathrm{eV}^2$. At what distance from a nuclear reactor would the first minimum in electron antineutrino flux occur, ignoring any influence of the MSW effect? Would you expect the MSW effect in either the earth, or in the earth's atmosphere, to noticeably influence the spatial distribution of the electron anti-neutrino flux?

(No More Problems)