Physics 225A Third Problem Set

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1. Here are some meson decays. For each, determine if the decay is totally forbidden, or allowed; if allowed, then say which interaction (strong, electromagnetic, weak) drives it, and make the simple Feynman diagram. If the decay is forbidden explain what stops it... you may have to draw upon earlier knowledge (like QM), or maybe even a little extra reading, in some cases.

   It will help to just look at the RPP tables first!

   (a) $\pi^0 \to \gamma\gamma$
   (b) $\pi^+ \to e^+\overline{\nu}_e$
   (c) $\eta \to \pi^0\pi^0$
   (d) $\eta \to \pi^+\pi^-\pi^0$
   (e) $\rho^0 \to \pi^0\pi^0$
   (f) $\rho^0 \to \pi^+\pi^-$
   (g) $\phi \to K^+K^-$
   (h) $K^+ \to \pi^+\pi^0$
   (i) $D^+ \to K^0\pi^+$
   (j) $D^0 \to K^-\pi^+$
   (k) $D^{\star 0} \to D^+\pi^-$
   (l) $J/\psi \to D^+D^-$
   (m) $D^{\star +} \to D^0\pi^+$

2. A heavy nucleus of mass M, and momentum $|\vec{p}|$ collides with an electron which is initially at rest, in the 'lab'. The final kinetic energy of the electron is w. Show that the the maximum w, w_{max}, is:

$$w_{max} = \frac{2m_e|\vec{p}|^2}{M^2 + m_e^2 + 2EM} \quad ,$$

   where $E = \sqrt{|\vec{p}|^2 + M^2}$, and m_e is the mass of the electron. A good start is to consider the 4-vector product $(p_e - p_e')^2$, for the electron, where the prime represents the final state, and compare evaluations in the lab and in the center of momentum frames.

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3. In an experiment, both signal (S) and background (B) events are present. You have an estimate of the mean signal-to-background ratio, $\rho = \overline{S}/\overline{B}$. But you are not sure, so you devote a fraction f of your running time to sampling $S + B$, and the remaining fraction $(1 - f)$ to sampling B alone. Show that the value of f which minimizes the statistical variance in the measured *rate* (events per unit time) of S is:

$$f = 1 + \frac{1}{\rho} - \frac{1}{\rho}\sqrt{1+\rho}$$

Describe the optimum f for $\rho = 0$ and $\rho = \infty$.

One good way to do this problem entails use of the 'propagation of errors,' namely, if you measure N_1 and N_2, and deduce S from a formula (where a and b are numbers) like:

$$S = aN_1 + bN_2$$

Then the relation between the variances (σ^2) is:

$$\sigma_S^2 = a^2\sigma_{N_1}^2 + b^2\sigma_{N_2}^2$$