PHYSICS 357S - Problem Set #3 - March 2003

Distributed **12th March**. Due to be handed in by **26th March** at class. After this date it should be handed to Stan Lai. Please be careful handing work in. Try to give it to Stan personally. Lost work cannot be given credit. Please talk to me or Stan if you have difficulties. We're here to help you.

This problem set counts for 10% of the grade. For the numerical values of constants, such as masses, (that I may have forgotten to give you!), you should use the Appendix A at end of the text book starting on page 377. Or you can look in the Review of Particle Physics;There should be a copy in the library. Or you can look on the Web at http://pdg/lbl.gov If you don't understand a question ask me about it. If you think there is a bug (error, typo, etc) in a question..tell me. You might be right!

1) Show that (explain why) if right-handed (helicity = +1) neutrinos are emitted in the β^- of the neutron, then it must be left-handed neutrinos that are emitted in the β^+ decay of the anti-neutron. Assume CP conservation.

2*)* The electromagnetic interaction conserves Parity. Show thatthis means that an unpolarized (random spin directions) source of γ -rays cannot emit circularly polarized photons.

This next part is quite subtle, see if you can do it with the hints! An electric discharge is produced in low pressure helium in a magnetic field. Red light emitted along the direction of the magnetic field is found to consist of two lines with a small wavelength separation dependant on the magnetic field. These lines had OPPOSITE circular polarizations. It does at first sight; because the energy of the photons seems to depend on the polarization, and would swap over under a parity transformation. *Hint*…. The photon direction is measured wrt to the direction of the B field, and the B field is an axial vector because it is caused by an electric current flowing clockwise or anti-clockwise? Is the polarization of the photon a vector or an axial vector? $\vec{S}_\gamma.\vec{B}$ is the relevant observable. Right hand polarization in the direction of the B-field is $\vec{S}_\gamma.\vec{B} > 0$, and $\vec{S}_\gamma.\vec{B} < 0$ is left-handed. How does $\vec{S}_\gamma.\vec{B}$ behave under the parity operation? Is parity conserved? Why?

3) Show that a scalar meson cannot decay into three pseudoscalar mesons in a parity conserving process.

4) Assume that a K^0 is produced at $t=0$.

(a) Show that the wave function of the K^0 at rest at time *t* can be written as:

$$|t\rangle = \sqrt{\frac{1}{2}}\left\{\left|K_1^0\right\rangle \exp\left(\frac{-im_1c^2t}{\hbar}-\frac{t}{2\tau_1}\right)+\left|K_2^0\right\rangle \exp\left(\frac{-im_2c^2t}{\hbar}-\frac{t}{2\tau_2}\right)\right\}$$

(b) Express $|t\rangle$ as a function of $\left|K^0\right\rangle$ and $\left|\bar{K}^0\right\rangle$.

(c) Derive the dependence of finding $\bar{K}^0$ at time *t* as a function of $\Delta m = m_1 - m_2$

(d) Sketch this probability for $\Delta m = 0$, $\Delta m = \frac{\hbar}{c^2\tau_1}$, and $\Delta m = \frac{2\hbar}{c^2\tau_1}$

5) Consider a system consisting of a positive and a negative pion, with orbital angular momentum *l* in the c.m.

(a) Determine the *C* parity of this $\left(\pi^+\pi^-\right)$ system

(b) If $l=1$ can the system decay into two photons? Why?

6) Much of what was initially learned about subatomic symmetries was learned from the pattern of meson decays. (What is a meson, by the way?). There are many different kinds of mesons with different spins, parities, etc. These quantum numbers depend on the quark content, and relative angular momentum. There is a meson called the η which is neutral and is an "isosinglet"; that means it has no charged partners. The neutral pion is a member of an isotriplet; it has positive and negative charged partners. The η is useful for testing *C*- invariance. Which of the following decays are allow and forbidden by *C*-invariance?

$$\eta \to \gamma\gamma$$
$$\eta \to \pi^0\gamma$$
$$\eta \to \pi^0\pi^0\pi^0$$
$$\eta \to \gamma\gamma\gamma$$
$$\eta \to \pi^+\pi^-\pi^0$$