PHYSICS 357S - Problem Set #2 - January 2003

Distributed **29th January**. Due to be handed in by **12th February** 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. 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) Which of the following reactions are allowed, and which forbidden, by the the conserved quantum numbers appropriate to the weak interaction?

$$\nu_\mu + p \rightarrow \mu^+ + n$$
$$\nu_e + p \rightarrow e^- + \pi^+ + p$$
$$\Lambda \rightarrow \pi^+ + e^- + \overline{\nu}_e$$
$$K^+ \rightarrow \pi^0 + \mu^+ + \nu_\mu$$

2) Classify the following experimentally observed process into strong, electromagnetic and weak interactions by considering the particles involved and the appropriate selections rules (i.e. quantum numbers conserved)

$$\pi^- + p \rightarrow \pi^+ + \pi^+ + n$$
$$\gamma + p \rightarrow \pi^+ + n$$
$$\nu_\mu + p \rightarrow \mu^- + n$$
$$\pi^0 \rightarrow e^+ + e^- + e^+ + e^-$$
$$p + \overline{p} \rightarrow \pi^+ + \pi^- + \pi^0$$
$$\tau^- \rightarrow \pi^- + \nu_\tau$$
$$D^- \rightarrow K^+ + \pi^- + \pi^-$$
$$\pi^- \rightarrow \pi^0 + e^- + \overline{\nu}_e$$
$$\Lambda + p \rightarrow K^- + p + p$$

3) A liquid hydrogen target of volume $10^{-4}\,\text{m}^3$ and density $71\,\text{kg m}^{-3}$ is exposed to a wide uniform monoenergetic beam of negative pions of flux 10^7 particles $\text{m}^{-2}\text{s}^{-1}$. The reaction $\pi^- + p \to K^0 + \Lambda$ is observed. If the cross section is 0.4 mb, what is the rate of production of Λ particles.

4) A high energy beam of neutrons of intensity $10^6\,\text{s}^{-1}$ traverses a target of ^{238}U in the form of a thin foil whose density per unit area is $10^{-1}\,\text{kg m}^{-2}$. If the elastic and inelastic cross sections are 1.4 barn and 2.0 barn respectively, calculate:

(a) the attenuation of the beam

(b) the rate of inelastic reactions

(c) the flux of elastically scattered neutrons 5 m from the target, averaged over all scattering angles.

5) As you probably know**,** atomic nuclei are labeled by $^A_Z X$. Z is the atomic number and is equal to the number of protons. It is also equal to the numbers of electrons, and hence gives the same information as *X,* the chemical symbol. *A* is the mass number of the nucleus and is equal to the number of protons plus the number of neutrons. The beta decay of a nucleus is when a neutron or proton undergoes weak decay (yes, a proton can "decay" when bound inside a nucleus). Now $^{64}_{29}Cu$ decays with a branching ratio of 62% to $^{64}_{28}Ni$, and with a branching ratio of 38% to $^{64}_{30}Zn$. In terms of the weak interaction explain how these two decays occur. The overall half life (time for a sample to decay by a factor of two) of $^{64}_{29}Cu$ is 12.8 hours. If someone only observes the electrons from the decay to $^{64}_{30}Zn$, how long does it take for them to see the intensity of this decay mode reduced by a factor of two?

6) Several broad $\pi^+ p$ resonant states, the Δ^{++}, are found with invariant masses ranging from 1.2 to $2.5\ \text{GeV}/c^2$. One state has a central mass of $1.62\ \text{GeV}/c^2$ and a width of $\Gamma = 150\ \text{MeV}/c^2$. If the state has a spin of $\text{J}=\frac{1}{2}$, what would the peak cross section for $\pi^+ p$ scattering via this intermediate short lived state?