# PHYSICS 489Y - Problem Set #1

## Due 2nd October

Do the following problems from the text book: 1.1, 1.3, 1.6,1.10, 2.3, 2.5, 2.15, 2.16.

Also do the two following problems.

**1)** Imagine an elastic scattering event between two particles having the same mass $m$ and in the CM frame they have 3-momentum $|\overline{p}|$. After this interaction the particles have the same $|\overline{p}|$, that's what we mean by elastic, and they have scattered through an angle $\theta$ in the CM frame. Just to clarify your thoughts sketch this interaction in the CM before and after the interaction. Since these are Lorentz invariant quantities, you can calculate them in any frame you like… and believe me, the CM frame is the one to use! Show that, for this special case of elastic 2-body scattering,

$$s = 4\left(\overline{p}^2 + m^2\right)$$
$$t = -2\overline{p}^2\left(1 - \cos\theta\right)$$
$$u = -2\overline{p}^2\left(1 + \cos\theta\right)$$

**2) a)** *K* mesons decay mostly via the following channel:

$$K^+ \rightarrow \mu^+ \nu_\mu$$

Assume that a *K* traveling at a speed v decays this way. If the $\nu_\mu$ emerges at $90^\circ$ to the original pion direction, show that the $\mu$ comes off at an angle of

$$\tan\theta = \left(1 - m_\mu^2/m_K^2\right)\Big/2\beta\gamma^2$$

This problem is described in the LAB frame. $m_K$ and $m_\mu$ are the rest masses of the *K* and muon, while the neutrino is massless. *( Neutrinos are not massless actually. They have tiny masses, as discovered first at Kamioka in Japan using neutrinos produced by cosmic ray interactions in the earth's atmosphere, and then at Sudbury (Ontario) Solar Neutrino Observatory, using neutrinos from the sun..*

**b)** If the *K* has a $\beta$ of 0.8 calculate the decay angle for the muon. Then do the same calculation if the particle decay process is $\pi^+ \rightarrow \mu^+\nu_\mu$. *(Take the mass of the $\pi$ to be 140 MeV/c$^2$, and the mass of the K$^+$ to be 493 MeV/c$^2$.)*

**c)** Suppose the pions have a momentum of 200 $GeV/c$ when they enter a long evacuated tunnel. Calculate what proportion of them decay in the tunnel if it is 340 m long. *( This is how neutrino beams are produced. The mean lifetime of the pion is* $2.6\times10^{-8}s$ *)*