University of Toronto PHY357S

Problem Set 1

due Monday, 21 January 2002

(Late penalty is 10% per day, and no problem set is accepted after January 23.)

Each problem is of equal weight, but **not all problems may be marked**.

These problems are primarily based on Chapters 1-3 of Martin and Shaw (M&S); information from Appendices A, B and E and the inside back cover of M&S may also be helpful.
If you have any questions, ask me or Stan, preferably before the last lecture prior to the due date.

1) What is the theoretical Dirac magnetic moment of the tau lepton
   a) in natural (particle physics) units? (*i.e.* in eV^n, where n is some integer)
   b) in SI units?

2) Consider a positron beam
   a) Draw all distinct (*i.e.* not related by time ordering) Feynman diagrams for the processes
      i) $e^+e^- \rightarrow \mu^+\mu^-$
      ii) $e^+e^- \rightarrow \mu^+\mu^- \gamma$
      Estimate the relative rate for process (ii) compared to process (i).
   b) Consider a positron passing through iron and interacting with an atomic electron to produce a $\mu^+\mu^-$ pair by the process $e^+e^- \rightarrow \mu^+\mu^-$?
      i) What is the minimum (*i.e.* threshold) momentum a positron must have for this process to be possible?
      ii) Use M&S equation 6.3b to calculate the interaction length (*i.e.* the inverse of the probablity per unit length) for this process if the positron momentum is 100 GeV.
   c) If a 100 GeV positron enters an iron calorimeter, estimate how many positrons will be produced in the shower.

3) Figure 1.2 of Martin and Shaw shows one of the discovery pictures of the positron. The magnetic field is perpendicular to the picture and you may assume the tracks are in the plane of the picture.
   a) What is the momentum (in MeV/c) of the charged particle before it enters the lead plate? You may assume the particle has unit charge (*i.e.* $q=e$) and that it is relativisitic (*i.e.* $\beta \approx 1$). Your answer must include an uncertainty (*e.g.* 7±1 MeV), so you may need to look at your old *First Year Physics Laboratory Manual* or at http://www.upscale.utoronto.ca/PVB/Harrison/ErrorAnalysis/All.html.
   b) How much energy would expected to be lost by the charged particle passing through the lead plate if it is
      i) a proton?
      ii) a positron?

4) For each part of this question, write down a process (*i.e.* an interaction or a decay) in which the initial state has strangeness S=–1 and which is:
   a) allowed by the strong interaction
   b) forbidden by the strong interaction but is allowed by the weak interaction
   c) forbidden by the strong, electromagnetic, and weak interactions, but is not forbidden by energy-momentum conservation.