Physics 129: Problem Set #1
Due: Wed Sept 5, 2001

This problem set covers material from Perkins Chapter 1. It also will introduce you to a very useful resource: the work of the Particle Data Group. I have also included a number of relativity problems. For those of you who are rusty on your special relativity, Tuan will be reviewing this topic in section next week.

1. *Natural Units* It is convenient to choose a set of units such that $\hbar = c = 1$. In such units, mass (m), momentum (mc) and energy (mc^2) are expreseed in units of GeV and length ($\hbar/mc$) and time ($\hbar/mc^2$) are expressed in units of GeV^{-1}.

   Show that in these units

   (a) the Compton wavelength of an electron is m^{-1}

   (b) the Bohr radius of the hydrogen atom is $(\alpha m)^{-1}$

   (c) the velocity of an electron in its lowest Bohr orbit is α

   Here m is the mass of the electron, or more precisely for parts b) and c) the reduced mass $m_e m_p/(m_e + m_p)$.

2. *Relativistic Kinematics and Fixed Target Collisions* Perkins 1.1

3. *Relativistic Kinematics and the Decay of the* π^0 Perkins 1.4

4. *Relativity and* β *decay* (adopted from Griffiths p. 52) In the period before the discover of the neutron, many people thought that the nucleus consisted of protons and *electrons*, with the atomic number equal to the excess number of protons over electrons. This view seemed to be supported by the observation that in nuclear beta decay electrons are emitted and the charge of the nucleus changes so that overall charge is conserved. Use the position-momentum uncertainty principle, $\Delta x \Delta p \geq \hbar$, to estimate the minimum momentum of an electron confined to a nucleus (radius 10^{-13} cm). From the energy-momentum relation (in natural units) $E^2 = p^2 + m^2$ determine the corresponding energy and compare

it with that emitted in, say, the beta decau of tritium (see Perkins p. 200). This result convinced some people (correctly) that the beta-decay electron could *not* have been rattling around inside the nucleus, but must be produced in the disintegration itself.

5. *Navigating the Particle Data Group Web Pages* The Particle Data Group maintains an excellent web site with a compilation of useful information about particle physics. This information is also available in printed form for free if you write to them. The PDG web address is: http://www-pdg.lbl.gov/

   The following questions can be answered just by looking up information on these web pages. They will just get you familiar with the pages and also some basic particle physics facts. (Hint: The first two questions can be answered by looking in the Summary Tables. The third uses information from available from the page of Reviews, Tables and Plots)

   (a) What are the masses of the lightest knownmeson, the lightest Spin 1 meson and the lightest meson that carries a strangeness quantum number of 1?

   (b) The Λ is a baryon that decays weakly. What is its mass and what is the lifetime of the Λ? What are the two most common decay modes of the Λ and fraction of the time does it decay into each of these two modes?

   (c) Consider the interaction $\pi^+ p \to \pi^+ p$ (πp elastic scattering). What is the experimentally measured cross section for each of the following center-of-mass energies: 1.2 GeV, 3 GeV, 6 GeV? How do these numbers compare to the total $\pi^+ p$ cross section ($\pi p \to anything$) at each of these energies?