Physics 457 Problem Set 1

Due in Class, January 12, 2005

This is a warm-up problem set that will help calibrate our background.

1. The discovery of the electron was evident in JJ Thomson's famous experiment because every "cathode ray" followed the same orbit indicating a unique ratio of charge to mass. In Thomson's experiment, electrons in a cathode ray tube were accelerated by an electric field created by a potential difference V. A magnetic field B perpendicular to to the electric field forced the electron orbits into circles with radius ρ.

a.) For this version of Thompson's experiment, derive an exact relativistic expression relating $e,\ m,\ B,\ \rho,$ and V.

b.) Show that this expression reduces to the non-relativistic result for e/m to lowest order in $\beta = v/c$.

2. Consider a 1 GeV muon produced in a cosmic ray interaction in the upper atmosphere. (High energy protons interact with atmospheric nuclei producing pions, which decay producing muons and neutrinos.) The muon rest mass is $m_\mu c^2 = 105.658$ MeV, and the lifetime is $\tau_\mu = 2.197\ \mu$s. .

a.) What are γ and v (or $1-\beta$) for muon.

b.) What is the momentum of the muon?

c.) What is the measured muon lifetime in frame of an observer on the surface of the Earth?

3. Which of the following quantities are relativisticly invariant (that is invariant under Lorentz transformations):

rest mass
electric charge
magnetic moment
spin
decay lifetime

4. Consider two distinct spin-1/2 particles (e.g. quark/antiquark) with spin's $\vec{s}_1$ and $\vec{s}_2$ forming a bound system (e.g. a meson).

a.) How many distinct quantum states are possible for this two–spin system?

b.) Express the spin wave-functions for all the possible quantum states, and classify them in terms of the total spin $\vec{s} = \vec{s}_1 + \vec{s}_2$ and s_z. You can use Pauli–spinor notation or bra-ket notation.