PHY4154 NUCLEAR AND PARTICLE PHYSICS

Assignment 1

(1) Find the speed at which a meter stick is moving if its length is observed to shrink to 0.5 m.

(2) Two bodies of mass m, each with speed $\frac{3}{5}c$, collide head on and stick together. What is the mass of the final clump?

(3) A body of rest mass m moving at speed v collides with and sticks to an identical body at rest. What is the mass and momemtum of the final clump?

(4) A muon has a proper lifetime of 2.0 μs. It is created 100 km above the earth and moves towards earth at 2.97×10^8 m/s. At what altitude does the muon decay? According to the muon, how far did it travel in its life?

(5) The muon decays as $\mu \to e\bar{\nu}_e\nu_\mu$. If the number of muons at $t = 0$ is N_0, the number N at time t is $N = N_0 e^{-t/\tau}$, where $\tau = 2.0$ μs is the proper lifetime of the muon. Suppose the muons move at speed $0.95c$. What is the observed lifetime of the muons? How many muons remain after traveling a distance of 3.0 km.

(6) Show that the energy-momentum relationship $E^2 = p^2c^2 + m^2c^4$ follows from the relations $E = \gamma mc^2$, and $p = \gamma mv$.

(7) A pion at rest decays to a muon and a neutrino. What is the speed of the muon? (You may answer in terms of m_π, m_μ etc.). On average how far will the muon travel (in vacuum) before disintegrating? (Use $m_\pi = 139.6\ \mathrm{MeV}/c^2$, $m_\mu = 105.7\ \mathrm{MeV}/c^2$ to give an answer in metres.)

(8) The Bevatron at Berkeley produced antiprotons by the reaction $p+p \to p+p+p+\bar{p}$, where on the LHC a high energy proton strikes a proton at rest. What is the minimum energy required for the striking proton?
Now assume that both the initial protons are moving (for a head-on collision). Now what is the minimum energy required by each initial proton for this reaction?

(9) An electron annhilates with a positron as follows: $e^- + e^+ \to \gamma + \gamma$. Let the positron be at rest initially, and the electron have kinetic energy of $1.0\ \mathrm{MeV}$. The emitted photons travel at angle θ with the electron's direction of motion. Determine the energy E, momemtum p and angle of emission θ of each photon. (Note: $m_e = 0.511\ \mathrm{MeV}/c^2$, $E_\gamma = pc$). What is the angle of emission θ if the electron has kinetic energy of $1.0\ \mathrm{GeV}$?

(10) Compton scattering: A photon of wavelength λ collides elastically with a charged particle of mass m. If the photon scatters at angle θ, show that its outgoing wavelength λ' is
$\lambda' = \lambda + (h/mc)(1 - \cos\theta)$.