PH110: Tutorial Sheet 1 (Quantum Mechanics)

This tutorial sheet deals with problems related to the relativistic energy-momentum conservation.

1. If a particle of rest mass m_0 has total energy $4m_0c^2$, what is its total momentum expressed in terms of m_0c? What will be the energy of this particle when its total momentum is $2m_0c$? Ans ($\sqrt{15}m_0c$, $\sqrt{5}m_0c^2$)

2. If a particle has the rest-mass energy of 100 MeV, what will be its total energy if it moves with the velocity: (a) $0.9c$, (b) $0.99c$, and (c) $0.999c$? (Useful info: 1 MeV $\equiv$ Million electron volts $= 1.0 \times 10^6$ eV)

3. A ρ-meson of rest-mass energy 760 MeV decays into two π-mesons each of rest-mass energy 150 MeV. What is the speed of one π-meson relative to the other? Ans: $0.997c$

4. A pion of rest mass energy 140 MeV decays into a muon of the rest-mass energy 100 MeV, and a neutrino of zero rest mass. In the rest frame of the pion, calculate the momentum and speed of the muon in the units of MeV/c and c, respectively. Ans (24.29 MeV/c, $0.324c$)

5. Let m_0 be the rest mass of an electron and its anti-particle positron. If a hypothetical particle X rest mass $4m_0$ is produced during a collision between an electron and a positron, answer the following:

   (a) if the momentum of the electron is $p\hat{k}$ and that of positron is $-p\hat{k}$, find p. Ans ($\sqrt{3}m_0c$)

   (b) if the electron is initially at rest and the positron has momentum $q\hat{k}$, find q and the speed with which X is produced. Ans: ($\sqrt{48}m_0c$, $\frac{\sqrt{3}}{2}c$)