Name(s): PHY-222 (Fall 2018), 09/12/18

Homework Assignment #2

(*Due Date*: Mon, 09/24, 04:10 pm, in class; Show all your work for full/partial credit)

2.1 *Relativistic Energy and Momentum* *(3 pts.)*
An unknown particle produced at the Large Hadron Collider is measured in a detector to have a total relativistic energy of 260 GeV and a momentum of 228 GeV/c.

(a) What is the mass of the particle (in GeV/c^2)? Can you identify its name (by searching on the internet for it)?

(b) What is the speed of the particle (in units of c) as it traverses the detector?

(c) Another one of these particles is produced with a speed of $0.4c$. Calculate its kinetic energy both relativistically and in non-relativistic approximation.

2.2 *Relativistic Dispersion Relation* (cf. Prob. 2.2.7 in textbook) *(1 pts.)*
Show that the relativistic "dispersion" relation, $E^2 = p^2c^2 + m^2c^4$, follows from $E{=}\gamma mc^2$ and $p{=}\gamma mu$. (*Hint: Insert E and p into the first equation and simplify.*)

2.3 *Nuclear Fusion Reactor* (cf. Prob. 2.2.14 in textbook) *(2 pts.)*
A promising source of energy are nuclear fusion reactors (more stable and with less radioactive products than fission reactors). Their basic reaction is the fusion of two forms of heavy hydrogen into helium and a neutron: $d + t \rightarrow {}^4He + n$.
The deuteron (d) consists of a neutron (n) and a proton (p) bound by $2.2\,MeV$, the triton (t) of 2 n's and a p bound by $8.5\,MeV$, and ${}^4He$ of 2 n's and 2 p's bound by $27.4\,MeV$. How much deuterium (in kg) is burnt in a $100\,MW$ fusion reactor in one month (assuming 50% energy efficiency of the reactor)?

2.4 *Conservation of Energy and Momentum* (cf. Prob. 2.4.22 in textbook) *(4 pts.)*
The ϕ meson (mass $m_\phi{=}1019\,MeV/c^2$) is an unstable particle mostly decaying into two K mesons ($m_K{=}494\,MeV/c^2$).

(a) For a ϕ at rest, calculate the momentum, energy, and speed of the decay kaons.

(b) If the ϕ meson is instead moving at a momentum of $P_\phi{=}500\,MeV/c$ in x-direction, and the kaon decay momenta are in the $\pm y$ direction in the rest frame of the ϕ, calculate the momenta (x- and y-components) of the kaons in the frame where ϕ is moving with $P_\phi{=}500\,MeV/c$.
(*Hint: use total-momentum conservation in x- and y-direction, $\vec{P}_\phi = \vec{p}_{K_1} + \vec{p}_{K_2}$; start by drawing the vector addition diagram and inferring the y-components.*)