Particle Physics - Exercises

Kinematics 13.1.11.

1. A particle of mass M decays into two particles of masses $m_{1,2}$.
In the rest system of the mother particle calculate the energies $E_{1,2}$ of the daughter particles!
How are the decay energies shared for the decays
$K^0 \rightarrow \pi^+ \pi^-$, $\Lambda \rightarrow p\ \pi^-$ and $\pi \rightarrow \mu\ \nu_\mu$?
Take into account that $m_{p,\Lambda} \gg m_{\pi,\mu} \gg m_\nu$! **[4]**

2. Calculate the kinematic threshold for the process $\nu_\tau\ e^- \rightarrow \tau^-\ \nu_e$! **[3]**

3. Ultra high-energetic cosmic protons can scatter on the 2.7 K cosmic microwave background radiation and produce neutral pions $p\ \gamma \rightarrow p\ \pi^0$ so that the universe becomes intransparent to cosmic protons above this pion production threshold.

- Calculate the energy threshold for this process! **[3]**
- Use Wien's law for the peak wave length $\lambda_{peak}/\text{nm} = 2.9 \cdot 10^6 / (T/K)$ to recalculate this energy threshold, the so-called GZK cut-off! **[2]**

4. The cosmic microwave background radiation has a density of about 400 photons per cm^3. What is the mean free path of cosmic protons in this radiation if the average proton-photon interaction cross section above the pion production threshold is 1 mb? Compare with the radius of the Milky Way of about 50.000 light years and discuss the possible origin of ultra-high energetic cosmic rays! **[2]**