EP 228 Particle Physics, Final Exam Questions

These are the final exam questions (starting from next page) of the course.
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Good Luck,
Prof. Dr. Ahmet Bingül

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1. Draw lowest order Feynman Diagrams for the following decays / reactions:

(a) $\overline{\nu_e} + p \rightarrow n + e^+$

(b) $\pi^- \rightarrow \mu^- + \overline{\nu_\mu}$

(c) $\gamma + p \rightarrow n + \pi^+$

2. According to a Grand Unified Theory (GUT), a proton can decay with a very long time in the mode $p \rightarrow \mu^+ + \pi^0$. Measurements taken at Super-Kamiokande detectors indicate that the half-life of protons is at least 7.7×10^{33} years.
See also: https://inspirehep.net/literature/1491380

(a) Show that this decay is forbidden.

(b) Estimate how long we would have to watch, on average, to see a proton in a glass of water (~200 ml) decay.

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2. Consider the reaction: $\gamma + p \rightarrow n + \pi^+$

(a) Calculate threshold momentum of the reaction for photon <u>if proton is at rest</u>. Namely, compute momentum of photon to start this reaction.

(b) Calculate the wavelength of the photon in part (a). What is the region of electromagnetic spectrum for this photon?

(c) Assume that the cross section for the reaction in part (a) is σ = 1 mb.
How many pions are generated per hour for the luminosity of $L = 10^{26}$ /(cm^2.s)?

(d) Calculate threshold kinetic energy for the proton if the collision is head-on.

In this case, assume that the photon is the cosmic microwave background radiation. Therfore, the energy of the photon is given by E_γ =kT where T = 2.7 K and k is the Boltzman constant.

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3. Consider the decay of neural *D* meson $D^0 \rightarrow \pi^- + e^+ + X$
See also: https://en.wikipedia.org/wiki/D_meson

(a) Determine the unknown particle X in the decay.

(b) Draw a Feynman Diagram for the decay.

(c) Calculate the maximum kinetic energy of the positron emitted in the decay if the D^0 is at rest?

(d) Now, assume that D^0 moves at v = 0.9*c* in a fixed direction and it decays after one mean lifetime. Calculate the decay length of D^0 in laboratory frame.
(*Decay length is the distance that a particle travels before it decays*).

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4. (a) Find the non-relativistic and relativistic kinetic energy, momentum, velocity of an electron accelerated by means of the potential difference V= 250 kV.

(b) Repeat your calculation for a proton.

5. Consider the cyclotron in our University. It accelerates protons to 19 MeV with a maximum orbital radius of 1 m. See lecture notes.

(a) Compute the strength of the required magnetic field *B.*

(b) Calculate the frequency of the RF supply?

(c) If the amplitude of the accelerating voltage (Dee voltage) is 50 kV, how many orbits are required to reach full energy?

(d) Calculate energy gained per revolution.