

Homework 3

12 bonus points

Problem 1 (2+2=4 points)

An experiment searching for proton decay in the mode $p \rightarrow \pi^0 + e^+$ is carried out using a cubical tank of water as the proton source. The signal is to be detected via Cherenkov light emitted when the electromagnetic showers from the decay products transverse water.

A) Estimate the total number of Cherenkov light photons emitted in the visible region of wavelength (2 points). Hint: first, calculate the total track length integral in an electromagnetic shower.

B) If the light is detected by an array of photomultiplier tubes (PMTs) at the water tank surfaces, what fraction of the surface must be covered by photocathode to give an energy resolution of 5%. Assume 20% photocathode efficiency and about 50% light losses due to the imperfect optical transmission of water. Hint: the number of detected photons N will be a measure of the energy ($E = \text{Const} \cdot N$), this number fluctuates approximately according to Poisson statistics. (2 points)

Problem 2 (2 points)

An experimental group searched for magnetic monopoles in cosmic rays with a detector of 1 m^2 cross section. If the experiment continued for 1 year and no monopole-like events were detected, what would the limit on the monopole flux $X \text{ m}^{-2}\text{yr}^{-1}$ at 95% confidence level be?

Problem 3 (3 points)

The main decay mode of a charged pion is $\pi^+ \rightarrow \mu^+ \nu$ and its lifetime $\sim 10^{-8} \text{ s}$.

The main decay mode of a neutral pion is $\pi^0 \rightarrow \gamma\gamma$ and its lifetime $\sim 10^{-16} \text{ s}$.

Starting from the quark structure of both pions, draw Feynman diagrams for both decays. (2 points)

Why are the two lifetimes so different? (1 point)

Problem 4 (3 points)

Which of three conservation laws would be violated if the following reactions were possible?

	Angular momentum?	Lepton number?	Baryon number?
$n \rightarrow p e^- \bar{\nu}_e$			
$n \rightarrow \pi^+ e^- \gamma$			
$n \rightarrow \nu + \gamma$			
$n \rightarrow \bar{p} + e^+ + \nu$			
$n \rightarrow \pi^+ e^- \bar{\nu}_e$			
$\pi^- \rightarrow \mu^- \gamma$			
$\Sigma^- \rightarrow \bar{p} \gamma$			
$\mu^- \rightarrow e^- \gamma$			
$\mu^- \rightarrow e^- \nu_e$			