University of Minnesota
School of Physics and Astronomy

2025 Fall Physics 8901
Elementary Particle Physics I

Assignment Solution

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Problem Set 2 due 9:30 AM, Monday, September 29th

Question 1

The $\tau - \theta$ Puzzle

In the 1950's, two particles τ, θ were discovered with the same mass and lifetime that decayed differently. At the time, physicists believed that parity was conserved in all interactions.

(a) Consider the decay $\theta \to \pi^+\pi^0$. Assuming parity invariance and zero for the spin of θ, find the parity of θ.

(b) Now consider the decay process $\tau \to \pi^+\pi^+\pi^-$. (This is an old symbol for the K meson.) Let l be the orbital angular momentum of $\pi^+\pi^+$ and l' the orbital angular momentum of π^- relative to the center-of-mass of $\pi^+\pi^+$. Assuming parity invariance and the spin of τ equal to zero, find its parity.

(c) What resolved the $\tau - \theta$ puzzle?

Answer

(a)

First, we note that the intrinsic parity of a pion is -1. The parity of a two-particle system is given by

$$P = P_1 P_2 (-1)^l, \tag{1}$$

where P_1 and P_2 are the intrinsic parities of the two particles, and l is their relative orbital angular momentum. Since the θ has spin 0, the two pions must have total angular momentum 0. The two pions are identical bosons, so they must be in a symmetric state. This means that l must be even. The lowest even value is $l = 0$. Thus, we have

(b)

(c)

Question 2

List all applicable conservation laws that are or would be violated in the following decays:

1. $\rho^0 \to \pi^0\pi^0$
2. $\rho \to \gamma\gamma$
3. $K^+ \to \pi^+\pi^0$
4. $\pi^0 \to 5\gamma$

(Look up the corresponding parities from the Particle Data Group at http://pdg.lbl.gov.)

Answer

Question 3

List all states (J^{PC}) with total spin $J = 0, 1, 2$ and P, C parities that cannot be realized as a fermion-antifermion system (i.e., as e^+e^- or quark-antiquark). (Hypothetical particles with such combinations of quantum numbers are called exotic, and are being sought for in experiments, so far unsuccessfully.)

Answer

Question 4

State which of the following combinations can or cannot exist in a state of isospin $I = 1$, and give the reasons:

1. $\pi^0\pi^0$
2. $\pi^+\pi^-$
3. $\Sigma^0\pi^0$
4. $\Lambda\pi^0$

Answer