

University of Minnesota  
School of Physics and Astronomy

**2025 Fall Physics 8901**  
**Elementary Particle Physics I**  
Assignment Solution

Lecture Instructor: Professor Tony Gherghetta

Zong-En Chen  
chen9613@umn.edu

September 18, 2025

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

## Question 1

### The $\tau - \theta$ Puzzle

In the 1950's, two particles  $\tau$ ,  $\theta$  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  $\theta \rightarrow \pi + \pi^0$ . Assuming parity invariance and zero for the spin of  $\theta$ , find the parity of  $\theta$ .
- (b) Now consider the decay process  $\tau \rightarrow \pi^+\pi^+\pi^-$ . (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  $\pi^-$  relative to the center-of-mass of  $\pi^+\pi^+$ . Assuming parity invariance and the spin of  $\tau$  equal to zero, find its parity.
- (c) What resolved the  $\tau - \theta$  puzzle?

## Question 2

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

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

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

### 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.)

## 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.  $\Lambda\pi^0$