PHYSICS 415/515 - Fall Semester 2025 - ODU

Nuclear and Particle Physics - Problem Set 7

Problem 1)

a) Write a short paragraph describing the experimental evidence for the existence of small (point-like) elementary particles (partons) inside the proton. What experiments were done? What peculiar feature was observed in the data? How was this interpreted?
b) Describe, in a few sentences, the basic ideas of the constituent quark model of hadrons (baryons and mesons). What kind of quarks does one need to describe the light hadrons (less than 2 GeV in mass)? How are they combined to make mesons? Baryons? Give two examples!
c) *Extra credit*: What is the relationship (and the **difference**) between the partons (part a) and the constituent quarks (part b)?

Problem 2)

For each of the following (real or hypothetical) reactions, write down whether they can occur in nature (i.e. whether they allowed by quantum number conservation) and which interaction is most likely involved. List any conservation laws that are **violated** by each event.

a) $\mu^- \rightarrow e^- \upsilon_\mu \bar{\upsilon}_e$
b) $\mu^- \rightarrow e^- \gamma$
c) $\pi^0 \rightarrow e^+ e^-$
d) $\Lambda^0 \rightarrow p e^- \bar{\upsilon}_e$
e) $\Delta^{++} \rightarrow p\pi^+$
f) $\mu^- \rightarrow \upsilon_\mu \, \gamma$
g) $p \rightarrow e^+ \bar{\upsilon}_e$

(If you forgot which quantum numbers are conserved by which interaction, you may have a peek at the reverse side…)

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Absolutely conserved quantum numbers (by all known interactions):

Energy E, momentum **p**, total angular momentum **J**, Charge Z, Baryon number A, total Lepton number $L_e + L_\mu + L_\tau$, CPT

Conserved by strong, electromagnetic and weak interactions:

Separate electron, muon and tau Lepton numbers L_e , L_μ , and L_τ

Conserved by strong and electromagnetic interactions:

Quark flavor (u,d,s,c,b,t) and Lepton flavor (e^-, μ^-, τ^-, ν_e , ν_μ , ν_τ), parity P, charge parity C, time reversal T

Conserved only by the strong interaction:

Total Isospin I