PHYSICS 415/515 - Fall Semester 2025 - ODU

Nuclear and Particle Physics - Problem Set 5 - Solution

Problem 1)

a) Going to the Particle Data Group web site, I found the following link: https://pdg.lbl.gov/2025/tables/contents_tables.html.
Scrolling through "Light unflavored mesons", I found on page 7 the following information on the Φ meson:
- Mass m = 1019 MeV
- Charge Z = 0 (inferred from decay modes and missing charge indicator)
- Strangeness S = 0 (because it's "unflavored")
- Spin J = 1, Parity P = -
- Most likely decay modes: $\Phi \to K^+K^-$ and $\Phi \to K^0{}_L K^0{}_S$ (83.5% together)

b) From the corresponding pages on K mesons (p. 25-33), I find the following quark composition:
$K^+ = u\bar{s}$, $K^0 = d\bar{s}$, $\overline{K}^0 = \bar{d}s$, $K^- = \bar{u}s$,.
This means that the Φ meson decays into two mesons, one with a s-quark and the other with an s-antiquark , 83.5% of the time. On the other hand, the decay products apparently can contain both u and d quarks and antiquarks.

c) Since the decay products seem do contain strange quarks in nearly all cases, it is likely that the Φ meson is mainly made of a strange + anti-strange quark pair ($s\bar{s}$). This would also explain is rather high mass compared to other "unflavored" mesons like the ρ and ω.

d) Since the total angular momentum is J=1, the two quark spins have to be parallel (Spin-1) if the orbital angular momentum is zero. This is likely true since the parity is negative, which comes from the opposite parity of a quark and its antiquark. If L=1, there would be an extra negative-parity factor which would make the overall parity positive.

Problem 2)

Again, I find all necessary information in the PDG book/website (look under "Baryons" and the page for Omegas. According to that page, the Ω^- baryon is a pure sss state (3 strange quarks). The total angular momentum is "predicted" by the quark model to be J=3/2, just like that of the Delta resonance. This means that the wave function must be completely symmetric in flavor (sss), in orbital wave function (ground state always has L=0) and in spin (all 3 quark spins are aligned). Since the color wave function is ALWAYS completely antisymmetric, the Pauli-Principle (Fermi statistics) is obeyed. However, we cannot have a spin-1/2 version (like the nucleon in the case of the Delta), since then the spin wave function would be no longer symmetric and therefore the total wave function no longer perfectly antisymmetric since all other parts of the wave function have to stay the same.