Joint Physics Analysis Center

Summer Workshop on the Reaction Theory
Exercise sheet 1

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Classwork

Meson Quantum Numbers in the Quark Model

Consider a two particle system, the $q\bar{q}$ system, which in the quark model form the mesons. Denote the quark q as particle 1 and the anitquark $\bar{q}$ as particle 2. The quarks have spin $s_q = 1/2$, mass m_q, and intrinsic parity $\eta_q = +1$. Let the four momentum and spin projection for the quark q be p_1 and σ_1, and for the $\bar{q}$ p_2, σ_2. A two quark system may be written in their center-of-momentum frame

$$|q(\mathbf{p}_1, \sigma_1)\, \bar{q}(\mathbf{p}_2, \sigma_2)\rangle \to |\widehat{\mathbf{p}}\, \sigma_1 \sigma_2\rangle \tag{1}$$

where $\widehat{\mathbf{p}} = (\theta, \varphi)$ is the orientation of q with respect to a defined coordinate system.

(1) In the LS coupling scheme, write the two particle state in the total angular momentum basis $|JM\ell\, s\rangle$.

(2) Determine the allowed quantum numbers for s, ℓ, and J

(3) Using the action of the parity $\mathcal{P}$ and c-parity $\mathcal{C}$ operators on the state $|JM\ell\, s\rangle$, determine the allowed parity and c-parity quantum numbers P and C. Determine the allowed J^{PC} numbers for the $q\bar{q}$ system through $J = 3$. List the states through $J = 3$ that are not allowed, the so-called 'exotic' states.

$$\mathcal{P}\,|JM\ell s\rangle = (-1)^{\ell+1}\,|JM\ell s\rangle \tag{2}$$

$$\mathcal{C}\,|JM\ell s\rangle = (-1)^{\ell+s}\,|JM\ell s\rangle \tag{3}$$