Partice Physics: Problem Sheet 3

Mesons & Baryons and the Strong Force

1. Draw a Feynman diagram for the process $p\pi \to \Delta^{++} \to p\pi$.

2. What is meant by colour confinement?

3. The ϕ meson decays via the strong force as follows:

$$\begin{aligned} \phi &\to K^+K^- && 49\% \\ &\to K^0\bar{K}^0 && 34\% \\ &\to \pi^+\pi^-\pi^0 && 17\% \end{aligned}$$

   What are the Q-values, the amount of kinetic energy produced in the decay, for these decays?

   Draw Feynman diagrams of the above decays and explain why the decays to kaons is favoured despite the low Q-value?
   Hint: You have to consider the colour charge of the gluons.

4. The J/ψ meson was discovery through its electromagnetic decays into e^+e^- and $\mu^+\mu^-$. However, the J/ψ decays mainly through strong interactions such as: $J/\psi \to \pi^+\pi^-\pi^0$.

   Draw the Feynman diagram for this decay, and hence explain why, although most of the decays of the J/ψ are due to the strong force, it has a relatively long lifetime.

5. Which of these processes occur in nature?

$$\begin{aligned} &a)\ \pi^-p \to K^0\Lambda^0 \\ &b)\ \pi^-p \to \pi^0\Lambda^0 \\ &c)\ \pi^-p \to K^+\Sigma^- \\ &d)\ \pi^-p \to \pi^+\Sigma^- \end{aligned}$$

   What quantum numbers are needed to solve this question? How are these related to the quark model?

6. Verify the quark model predictions given in the lectures for the masses of the following mesons: π, K, ρ, ω, K^* and ϕ. Assume $m_u = m_d = 310$ MeV and $A = (2m_u)^2 \cdot 160$ MeV.

7. We saw in the lectures there are eight gluons: $\mathrm{r\bar{b}}, \mathrm{r\bar{g}}$, $\mathrm{b\bar{g}}$, $\mathrm{b\bar{r}}$, $\mathrm{g\bar{r}}$, $\mathrm{g\bar{b}}$, $(\mathrm{r\bar{r}} - \mathrm{g\bar{g}})/\sqrt{2}$ $(\mathrm{r\bar{r}} + \mathrm{g\bar{g}} - 2\mathrm{b\bar{b}})/\sqrt{6}$.

   Since there are three colour and three anti-colours, you might expect that there are nine gluons. Why doesn't the ninth combination allowed by symmetry:
   $(\mathrm{r\bar{r}} + \mathrm{g\bar{g}} + \mathrm{b\bar{b}})/\sqrt{3}$ describe a gluon?

8. *Non-examinable!* On the back of this sheet are the Clebsh-Gordon coefficients describing isospin addition. Use these to confirm the isospin sums for π^+p, π^-p and π^0n we saw in lecture 6.