Exercise 6 Return by 16.00 on Tue 6.11.

1. Let us continue our studies about the $\eta(547)$ meson. In previous exercise we found that it can decay to three pions conserving parity, but for example decay to two pions was not possible.

   Experimentally the most probable decay channels for η and their branching rations are

   $$B(\eta \to \gamma + \gamma) = 39\%$$
   $$B(\eta \to \pi^0 + \pi^0 + \pi^0) = 33\%$$
   $$B(\eta \to \pi^+ + \pi^- + \pi^0) = 23\%.$$

   On the other hand the decay channel $\eta \to \gamma + \gamma + \gamma$ has not been observed (experimentally the branching ratio is measured to be $< 1.6 \cdot 10^{-5}$).

   (a) Figure out the C parities of the η meson and of the photon.

   (b) Naively one would guess that η decays into the pion channel mostly trough the strong interaction, whereas decay into the photon channel happens trough the electromagnetic interaction, and thus the pion channel should dominate. However experimentally we see that all these channels are roughly equally probable. Thus we can conclude that also the decay to pions goes trough the electromagnetic interaction.

   Explain this observation as follows: η is an isospin singlet $|I = 0, I_3 = 0\rangle$ and neutral pion is $|I = 1, I_3 = 0\rangle$. Couple first the two pions with each other and then this system with the third pion and show that decay $\eta \to \pi^0 + \pi^0 + \pi^0$ would break the isospin conservation. The same explanation works for the $\eta \to \pi^+ + \pi^- + \pi^0$ channel (you don't have to derive this).

2. Examine the processes

   $$K^- p \to K^- p \quad \text{and} \quad K^- p \to \overline{K^0} n.$$

   Draw the quark diagrams and figure out if a resonance is possible in these processes.

3. Using the isospin invariance of the strong interaction show the following ratio for the cross sections

   $$\frac{\sigma(pp \to \pi^+ d)}{\sigma(np \to \pi^0 d)} = 2.$$

   The deuteron (d) isospin is $I_d = 0$ and the pion isospin is $I_\pi = 1$.

4. The baryonic resonance N^+ has isospin $I = I_3 = \frac{1}{2}$. Show using isospin invariance that

   $$\frac{\Gamma(N^+ \to n\pi^+)}{\Gamma(N^+ \to p\pi^0)} = 2.$$

5. Using the isospin symmetry and the facts given on page 184 in the lecture notes about resonance cross sections, explain the result (=derive)

   $$\frac{\sigma_{\text{tot}}^{\pi^+ p}(\sqrt{s} = m_\Delta = 1232\,\text{GeV})}{\sigma_{\text{tot}}^{\pi^- p}(\sqrt{s} = m_\Delta = 1232\,\text{GeV})} = 3$$

   Compare with experimental data (lecture notes page 181).