Exercise sheet № 2 - Introduction, symmetries

(Suggestion: draw the Feynman diagrams of all the reactions.)

1. What is the relative angular momentum ℓ in the final state of the decay $\Delta^{++} \to p\pi^+$?

2. Find the proportion of the branching fractions of the decays $K^{*+} \to K^0\pi^+$ and $K^{*+} \to K^+\pi^0$. For each of them, obtain a decay with a similar branching fraction by a simple rotation in the isospin space.

3. Find the relative proportions of the decays $\Sigma^{*0} \to \Sigma^+\pi^-$, $\Sigma^{*0} \to \Sigma^0\pi^0$ and $\Sigma^{*0} \to \Sigma^-\pi^+$.

4. The largest branching fraction of ρ^0 decays corresponds to $\rho^0 \to \pi\pi$.
   (a) Which interaction is responsible for this decay? Give as much arguments as possible.
   (b) Examine the conservation of P in the decay. Using symmetry considerations, show that the final state $\pi^0\pi^0$ is forbidden.
   (c) Study the conservation of C in the decay. What can be concluded?
   (d) Draw a similar conclusion by looking at isospin conservation, and make a comment on the comparison between the conclusions of (b), (c) and (d).
   (e) Draw the Feynman diagram of the decay.
   (f) Interpret the branching fraction of the decay $\rho^0 \to \pi^+\pi^-\pi^0$ and that of $\rho^0 \to \pi^+\pi^-\pi^0\pi^0$.

5. Study the coherence between the different quantum numbers (J^{PC} from the PDG, orbital angular momentum from the particle name) of the $c\bar{c}$ mesons: $\eta_c(1S)$, $J/\psi(1S)$, $\chi_{c0}(1P)$, $h_c(1P)$ and $\psi(2S)$. For each meson, give the possible pure spin state(s).

6. Using the relevant discrete symmetry (and the right arguments), show that the decay $\omega \to \pi^0\gamma$ is allowed, but that $\omega \to \pi^0\gamma\gamma$ is forbidden.

7. Shaw that the two- and three-pions final states in the decays of neutral kaons are well defined CP eigenstates. Find their CP contents.

8. The meson $\phi(1020)$ is a $s\bar{s}$ state, decaying to K^+K^- and $K^0\overline{K}^0$ (through which interaction?).
   (a) Study the conservation of P and C in these decays.
   (b) Making the (good) approximation that K^0_S and K^0_L are CP eigenstates with $CP = +1$ and $CP = -1$, respectively, explain the fact that the $K^0\overline{K}^0$ final state is observed only as $K^0_SK^0_L$, and not as $K^0_SK^0_S$ or $K^0_LK^0_L$.

9. Obtain a general expression for the kinematic boundaries of the Dalitz plot. Interpret the corners of the allowed region in term of momenta of the final state particles. Apply to the decay $B^0 \to D^0K^+\pi^-$

10. For each of the processes below, determine whether it is allowed or forbidden in the standard model. For the forbidden processes, explain why they are forbidden, giving *all the possible reasons* (here we do not require to take into account multiplicative quantum numbers and angular momentum). For the allowed processes, specify and justify by which *dominant* interaction they occur and draw the corresponding Feynman diagrams (one per process). Give all the relevant arguments you find to justify the interaction. Note on the diagram the names of all real and virtual particles.

1. $\Sigma^+ \longrightarrow \Lambda\mu^+\nu_\mu$
2. $D^+ \longrightarrow p\tau^-\nu_\tau$
3. $e^-p \longrightarrow e^-n\pi^+$
4. $B^0 \longrightarrow \tau^+\tau^-$
5. $e^+e^- \longrightarrow \gamma\gamma$

11. The same questions with more diagrams for self training (no solution will be provided).

1. $\gamma\, p \longrightarrow e^-\, \gamma$
2. $e^+e^- \longrightarrow W^-W^+$
3. $\nu_e e^- \longrightarrow \nu_e e^-$
4. $e^+e^- \longrightarrow \nu_\tau\bar{\nu}_\tau$
5. $\mu^- \longrightarrow \tau^-\bar{\nu}_\tau\nu_\mu$
6. $\tau^- \longrightarrow \mu^-\bar{\nu}_\mu\nu_\tau$
7. $\tau^- \longrightarrow e^-\bar{\nu}_\mu\nu_\tau$
8. $\tau^- \longrightarrow e^-\bar{\nu}_e\nu_\tau$
9. $\pi^+ \longrightarrow \mu^+\bar{\nu}_e$
10. $\pi^+ \longrightarrow \mu^+\nu_e$
11. $K^+ \longrightarrow \mu^+\nu_\mu$
12. $K^+ \longrightarrow \pi^+\pi^0$
13. $K^+ \longrightarrow \pi^+\pi^-\pi^+$
14. $K^+ \longrightarrow \pi^+\pi^+e^-\bar{\nu}_e$
15. $K^+ \longrightarrow \pi^+\mu^-e^+$
16. $K^0 \longrightarrow \mu^+\mu^-$
17. $\pi^0 \longrightarrow \mu^+\mu^-$
18. $p \longrightarrow e^+\gamma$
19. $p \longrightarrow e^+\pi^0$
20. $p \longrightarrow ne^+\nu_e$
21. $n \longrightarrow p\nu_e\bar{\nu}_e$
22. $\Delta^{++} \longrightarrow p\pi^+$
23. $\Delta^{++} \longrightarrow p\gamma$
24. $\Lambda^0 \longrightarrow p\pi^-$
25. $\Sigma^0 \longrightarrow \Lambda^0\gamma$
26. $\Sigma^- \longrightarrow n\pi^-$
27. $\Omega^- \longrightarrow \Lambda^0\pi^-$
28. $\pi^+ \longrightarrow \mu^-e^+e^+\nu_\mu$
29. $\gamma \longrightarrow e^-e^+$
30. $B^0 \longrightarrow D^{*-}D^0K^+$
31. $\tau^+n \longrightarrow \overline{\nu}_\tau\Delta^0p$
32. $\pi^+p \longrightarrow K^+\Sigma^+$
33. $\pi^+e^- \longrightarrow \overline{\nu}_e\mu^+\nu_\mu$
34. $B^+ \longrightarrow K^+\pi^0$