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 $c\overline{c}$ 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. For the forbidden processes, explain why, giving *all the possible reasons* (here we do not require to take into account multiplicative quantum numbers, angular momentum or isospin). For the allowed processes, specify and justify by which *dominant* interaction they occur and draw the corresponding Feynman diagrams (one per process). Note on the diagram all the particles (including 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. $B^+ \longrightarrow K^+\pi^0$