Particle Physics Worksheet #1

1. Particles are divided into fermions and bosons. What property of particles is used in order to make this classification?

2. State the Pauli exclusion principle and use it to explain why the innermost "shell" of an atom can have at most two electrons.

3. Very large numbers of photons in a laser beam occupy the same energy state. Explain why this is not a violation of the Pauli exclusion principle.

4. The idea of a particle exchange in an interaction is sometimes explained as follows:

   > You stand on ice (no friction) and throw a heavy ball to a friend. Throwing the ball makes you move away. When your friend catches the ball, he moves away.

   This explains a repulsive force. How would you change the description to explain an attractive force?

5. Neutrinos are electrically neutral. How do we distinguish neutrinos from antineutrinos?

6. Give the quark structure of
   (a) the antineutron
   (b) the antiproton

7. Explain, in terms of quarks, what is meant by the term
   (a) hadron
   (b) meson
   (c) baryon

8. What is the baryon number of the quark combination $\bar{c}\bar{c}\bar{c}$?

9. Determine whether the following reactions conserve or violate baryon number.
   (a) $p^+ \rightarrow e^- + \gamma$
   (b) $p^+ + p^+ \rightarrow \pi^+ + \pi^-$
   (c) $p^+ + p^- \rightarrow \pi^+ + \pi^- + n + \bar{n}$
   (d) $\Lambda^0 \rightarrow \pi^+ + \pi^-$

10. In the reaction $p + p \rightarrow p + p + X$, which baryon could X stand for?

11. The quark content of a certain meson is $(d\bar{s})$.
    (a) What is its charge and strangeness?
    (b) Is it is own antiparticle?

12. Determine whether the following reactions conserve strangeness.
    (a) $\pi^- + p^+ \rightarrow K^0 + \Lambda^0$
    (b) $\pi^0 + n \rightarrow K^+ + \Sigma^-$
    (c) $K^0 \rightarrow \pi^- + \pi^+$
    (d) $\pi^- + p^+ \rightarrow \pi^- + \Sigma^+$

13. The neutral meson $\eta_c = (c\bar{c})$ is its own antiparticle, but the neutral $K^0 = (d\bar{s})$ is not. Explain why.

14. What is the charge and strangeness of the baryon $\Lambda = (uds)$? Since the three quarks in this baryon have different flavors, Pauli's exclusion principle is satisfied. Does this mean that all three quarks could then have the same color? Why or why not?

15. In the reactions listed below, various neutrinos appear. In each case, identify the correct neutrino (or antineutrino).
    (a) $\pi^+ \rightarrow \pi^0 + e^- + \nu$
    (b) $\pi^+ \rightarrow \pi^0 + \mu^+ + \nu$
    (c) $\tau^+ \rightarrow \pi^- + \pi^+ + \nu$
    (d) $p^+ + \nu \rightarrow n + e^-$
    (e) $\tau^- \rightarrow e^- + \nu + \nu$

16. Do the following reactions conserve lepton number?
    (a) $p^+ \rightarrow e^+ + \pi^0$
    (b) $\pi^0 \rightarrow e^+ + \mu^-$
    (c) $\tau^+ \rightarrow \pi^+ + \bar{\nu}_\tau$
    (d) $\pi^- \rightarrow e^- + \bar{\nu}_e$

17. The reactions listed below are all impossible because they violate one or more conservation laws. In each case, identify the law that is violated.
    (a) $K^+ \rightarrow \mu^- + \bar{\nu}_\mu + e^+ + e^+$
    (b) $\mu^- \rightarrow e^+ + \gamma$
    (c) $\tau^+ \rightarrow \gamma + \bar{\nu}_\tau$
    (d) $p + n \rightarrow p + \pi^0$
    (e) $e^+ \rightarrow \mu^+ + \bar{\nu}_\mu + \bar{\nu}_e$
    (f) $p \rightarrow \pi^+ + \pi^-$

18. Explain what is meant by the term "confinement" in relation to quarks and gluons.