Name_____

Phys 4900, Fall 2011
Quiz #1

1. Define (as understood in the modern Standard Model):

a) Baryon

A baryon is a particle made of three quarks. (That is, the (net) quark content is three quarks, of any flavors. They are "colorless" by virtue of containing all three colors at once.

b) Meson

A meson is a quark--antiquark pair. They are colorless by virtue of containing only color-anticolor combinations.

c) Hadron A hadron is any particle which can interact strongly. Note, they can have electro-weak interactions.

d) Lepton

Any particle which can not interact strongly. These include the different versions of the electron and neutrino.

e) Flavor

A specification of the type of quark. Quarks come with charges of $+\frac{2e}{3}$ or $-\frac{e}{3}$ depending on their flavor.

2. Give the argument (which arose on one of the homework problems) as to how there could not be free electrons inside the nucleus which might pop out as a "beta decay".

3. a) Name (give the symbols) of any two members of the (ground state) baryon octet beside the proton and neutron.

Others are the singly strange

$$\Sigma^-,\ \Sigma^0,\ \Sigma^+ \quad \text{and} \quad \Lambda$$

and the doubly strange

$$\Xi^-,\ \Xi^0$$

b) Name *any* four members of the (ground state) meson octet.

They are the nonstrange

$$\pi^-,\ \pi^0,\ \pi^+,\ \eta$$

the $S = +1$

$$K^0,\ K^+$$

and the $S = -1$

$$K^-,\ \bar{K}^0$$

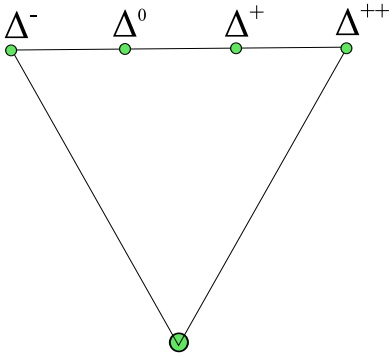
4.a) What is the quark content of the proton?

It is uud.

b) What is the quark content of the "J/Ψ" particle (discovered in 1974; now usually called Ψ).

It was the first particle with charm detected; it is a meson with content $c\,\bar{c}$. The discover of a new flavor had the effect of convincing everyone that the quark business was for real.

5. Give the name of the particle that occupies at the bottom of the baryon decuplet (a little of which is shown here) and give its quark content.



This is the Ω^- particle. It is sss.

6. The fact that the Cabibbo-Kobayashi-Maskawa matrix is not *diagonal* allows certain processes to happen. What processes are these?

It permits quarks to undergo a weak decay and jump between the generations. If the KM matrix were diagonal a d quark could decay to a u quark but an s quark could not do this.

7. Are the following reactions/decays allowed according to the standard model? If allowed, state which interaction is probably (mostly) responsible. If not allowed, say why!

a) $\mathrm{p} + \mathrm{p} \rightarrow \mathrm{p} + \pi^+ + \pi^0$

Illegal! Baryon number is not conserved. ($+2$ on left, $+1$ on right.)

b) $\pi^0 \rightarrow \mu^+ + e^-$

Illegal! Muon and electron lepton numbers are not separately conserved!

c) $\tau^- \rightarrow \bar{\mathrm{p}} + \pi^0$

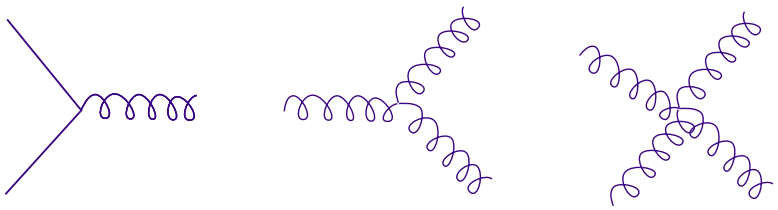
Illegal! Tau lepton number and baryon number not conserved!

d) $\nu_\mathrm{e} + \mathrm{n} \rightarrow \mathrm{e}^- + \mathrm{K}^0 + \mathrm{p}$

This one is OK. As it does not conserve strangeness (the K has strangeness) it must go by a weak interaction. I just pulled it out of a paper I saw on the archiv! (Where it was meant to be legal!)

8. Draw the 3 (legal) vertices (basic particle–particle interactions) of QCD.

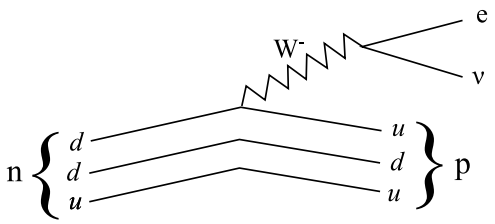
The vertices (basic interactions) in QCD are quark-gluon, three-gluon and four-gluon:



9. Draw the diagram for neutron decay:

$$\mathrm{n} \to \mathrm{p} + e^- + \bar{\nu}_\mathrm{e}$$

as it occurs at the quark (fundamental) level.



10. Give or take an order of magnitude, what is the lifetime of the muon?

$$2 \times 10^{-6} \text{ s}$$

11. To the best of your understanding, what is meant by the following properties of QCD:

a) Asymptotic freedom

The is the property of the QCD interaction whereby quark interactions at high energy/short distances become very weak.

b) Confinement

The is the property of the QCD interaction whereby quark interactions at low energy/large distances become very strong, so much so that rather than permit a quark to escape to infinity, $q\,\bar{q}$ pairs which appear to form new multi-quark particles.