Particle Physics Worksheet #1

(1) spin - fermions have $\frac{1}{2}$ integer spins
- bosons have integer spins.

(2) in a closed system, no two electrons can occupy the same quantum state
- the electrons in the innermost shell have opposite spins
- there are only two choices for spin, therefore only two electrons can fit in the shell.

(3) photons are bosons
- bosons do not obey the Pauli exclusion principle.

(4) - both friends stand with their backs to each other on the ice
- both throw a heavy ball
- throwing the balls allows the friends to move together

(5) - antineutrinos have opposite spin

(6) (a) $\bar{u}\bar{d}\bar{d}$ (b) $\bar{u}\bar{u}\bar{d}$

(7) (a) hadrons are made of quarks
(b) mesons are made of a quark and an antiquark, the quarks are of a color and its anticolor
(c) baryons are made of three quarks, one of each color

(8) $-\frac{1}{3} + -\frac{1}{3} + -\frac{1}{3} = -1$

(9) Baryons have a baryon number of +1 (p^+, Λ^0, n)
Antibaryons have a baryon number of −1 ($p^-, \bar{n}$)
(a) violate (b) violate (c) conserve (d) violate

(10) nothing

(11) (a) charge = 0, strangeness = +1
(b) no

(12) (a) $\pi^- + p^+ \rightarrow K^0 + \Lambda^0$ conserved.

$S = 0 + 0 \overset{?}{=} +1 \quad -1$

(b) $\pi^0 + n \rightarrow K^+ + \Sigma^-$ conserved.

$S = 0 + 0 \overset{?}{=} +1 + -1$

(c) $K^0 \rightarrow \pi^- + \pi^+$ not conserved

$S = +1 \overset{?}{=} 0 + 0$

(d) $\pi^- + p^+ \rightarrow \pi^- + \Sigma^+$ not conserved.

$S = 0 + 0 \overset{?}{=} 0 + -1$

(13) - an antiparticle has opposite quarks
the opposite of $c\bar{c}$ is $\bar{c}c$ which is the same
however, the opposite of $d\bar{s}$ is $\bar{d}s$ which is a different particle.

(14) $\Lambda = uds$

Charge $= \frac{2}{3} + \frac{-1}{3} + \frac{-1}{3} = 0$

strangeness $= -1$

no, all three quarks must be different colors
baryons appear colorless as defined by QCD and
the confinement principle.

(15) lepton number must be conserved.

(a) $\pi^+ \rightarrow \pi^0 + e^- + \nu$ $\quad \bar{\nu}_e$

$L_e \quad 0 \quad 0 \quad +1 \quad \underline{-1}$

(b) $\pi^+ \rightarrow \pi^0 + \mu^+ + \nu$ $\quad \nu_\mu$

$L_\mu \quad 0 \quad 0 \quad -1 \quad \underline{+1}$

(c) $\tau^+ \rightarrow \pi^- + \pi^+ + \nu$ $\quad \bar{\nu}_\tau$

$L_\tau \quad -1 \quad 0 \quad 0 \quad \underline{-1}$

(d) $p^+ + \nu \rightarrow n + e^-$ $\quad \nu_e$

$L_e \quad 0 \quad \underline{+1} \quad 0 \quad +1$

(e) $\tau^- \rightarrow e^- + \nu + \nu$ $\quad \bar{\nu}_e, \bar{\nu}_\tau$

$L_e \quad 0 \quad +1 \quad -1 \quad 0$

$L_\tau \quad +1 \quad 0 \quad 0 \quad -1$

(16) (a) no (only one lepton)

(b) no (only one lepton of each type)

(c) $\tau^+ \rightarrow \pi^+ + \bar{\nu}_\tau$

$L_\tau \quad -1 \overset{?}{=} 0 + -1$ yes

(d) $\pi^- \rightarrow e^- + \bar{\nu}_e$

$L_e \quad 0 \overset{?}{=} +1 + -1$ yes

(17) (a) $K^+ \rightarrow \mu^- + \bar{\nu}_\mu + e^- + e^-$ electron lepton numser

$L_e \quad 0 \overset{?}{=} 0 + 0 + 1 + 1$

(b) $\mu^- \rightarrow e^- + \gamma$ both muon and electron lepton number

(c) $\tau^+ \rightarrow \gamma + \bar{\nu}_\tau$ charge conservation

(d) $p^+ + n \rightarrow p^+ + \pi^0$ baryon number

$B = 1 + 1 \overset{?}{=} +1 + 0$

(e) $e^+ \rightarrow \mu^+ + \bar{\nu}_\mu + \bar{\nu}_e$ muon lepton number

$L_\mu \quad 0 \overset{?}{=} -1 + -1 + 0$

(f) $p^+ \rightarrow \pi^+ + \pi^-$ charge conservation

(18) - quarks cannot be isolated and therefore they cannot be observed.

- the color force between the quarks (mediated by gluons) is constant regardless of separation distance
- therefore, it would take an infinite amount of energy to separate the quarks.