

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) $\bar{u}\bar{u}\bar{d}$ (c) $\bar{d}\bar{d}\bar{d}$
- 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.
 $S = 0 + 0 = +1 - 1$
- (b) $\pi^0 + n \rightarrow K^+ + \Sigma^-$ conserved.
 $S = 0 + 0 = +1 + -1$
- (c) $K^0 \rightarrow \pi^- + \pi^+$ not conserved
 $S = +1 = 0 + 0$
- (d) $\pi^- + p^+ \rightarrow \pi^- + \Sigma^+$ not conserved.
 $S = 0 + 0 = 0 + -1$

- (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) $\Lambda = u d s$
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) $\pi^+ \rightarrow \pi^0 + e^- + \nu_e$
 $L_e 0 \quad 0 \quad +1 \quad \underline{-1}$

(b) $\pi^+ \rightarrow \pi^0 + (\mu^+ + \nu_\mu)$
 $L_\mu 0 \quad 0 \quad -1 \quad \underline{+1}$

(c) $\tau^+ \rightarrow \pi^+ + \pi^+ + \nu_\tau$
 $L_\tau -1 \quad 0 \quad 0 \quad \underline{-1}$

(d) $p^+ + \nu \rightarrow n + e^-$
 $L_e 0 \quad \underline{+1} \quad 0 \quad +1$

(e) $\tau^- \rightarrow e^- + \nu + \bar{\nu}_e$
 $L_e 0 \quad +1 \quad -1 \quad 0$
 $L_\tau +1 \quad 0 \quad 0 \quad +1$

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

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

(c) $\tau^+ \rightarrow \pi^+ + \bar{\nu}_\tau$
 $L_\tau - 1 = 0 + -1$ yes

(d) $\pi^- \rightarrow e^- + \bar{\nu}_e$
 $L_e 0 = +1 + -1$ yes

(17) (a) $K^+ \rightarrow (\mu^- + \bar{\nu}_\mu + e^- + e^-)$ electron lepton number
 $L_e 0 = 0 + 0 + 1 + 1$

(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
 $B = 1 + 1 = +1 + 0$

(e) $e^+ \rightarrow (\mu^+ + \bar{\nu}_\mu + \bar{\nu}_e)$ muon lepton number
 $L_\mu 0 = -1 + -1 + 0$

(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.