Homework 6

PHYSICS 304
March 6, 2020

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Chapter 15

6. Since the lepton numbers L_μ and L_e must be conserved,

$$\mu^+\colon L_\mu = -1$$
$$\mathrm{e}^-\colon L_\mathrm{e} = 1$$

The neutrinos must be one muon antineutrino ($\bar{\nu}_\mu$, $L_\mu = -1$) and an electron neutrino (ν_e, $L_e = 1$).

8. (a) $\bar{\nu}_\mu$ ($L_\mu = -1$)
   (b) ν_μ ($L_\mu = 1$)
   (c) $\bar{\nu}_e$ ($L_e = -1$)
   (d) ν_e ($L_e = 1$)
   (e) ν_μ ($L_\mu = 1$)
   (f) ν_μ ($L_\mu = 1$), $\bar{\nu}_e$ ($L_e = -1$)

9. (a) Cannot occur; baryon number is not conserved. $B: +1 \to 0$.
   (b) Can occur? Wouldn't this violate conservation of energy though?
   (c) Cannot occur; baryon number is not conserved.
   (d) Can occur.
   (e) Can occur.
   (f) Cannot occur; muon and baryon number are not conserved.

11. (a) Muon and electron number are not conserved.
    (b) Electron number is not conserved.
    (c) Strangeness is not conserved.
    (d) Electron and baryon number are not conserved.
    (e) Strangeness and the baryon number are not conserved.

12. (a) Muon and electron lepton numbers are not conserved.
    (b) Charge is not conserved.
    (c) Baryon number is not conserved.
    (d) Baryon number is not conserved.
    (e) Charge is not conserved.

17. Using the hadron compositions,

$$\Sigma^0 + p \to \Sigma^+ + \gamma + ?$$
$$\mathrm{uds} + \mathrm{uud} \to \mathrm{uus} + \gamma + \boxed{\mathrm{udd}}$$

The particle is a neutron (udd).

18. If we sum the quark constituents of each, they equal the values of the K^0 and Λ^0 particles.

	d	$\bar{\mathrm{s}}$	K^0	u	d	s	Λ^0
Q	$-\frac{1}{3}$	$\frac{1}{3}$	0	$\frac{2}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$	0
B	$\frac{1}{3}$	$-\frac{1}{3}$	0	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	1
S	0	1	1	0	0	-1	-1

28. As the momentum of the pion is zero, the total momentum must be conserved. Then $|p_\mu| = |p_{\bar{\nu}}|$. Using the energy-momentum relationship,

$$\begin{aligned} (E_\mu)^2 &= (pc)^2 + \left(m_\mu c^2\right)^2 \\ (E_\nu)^2 &= (pc)^2 && \text{Zero rest mass} \\ (E_\mu)^2 - (E_\nu)^2 &= \left(m_\mu c^2\right)^2 && (*) \end{aligned}$$

From conservation of energy,

$$\begin{aligned} E_\pi &= E_\mu + E_{\bar{\nu}} \\ E_\pi - E_{\bar{\nu}} &= E_\mu \\ (E_\pi - E_{\bar{\nu}})^2 &= (E_\mu)^2 \end{aligned}$$

Subtracting the square neutrino energy to achieve the form of $(*)$, we can then expand the LHS polynomial and substitute in $(*)$,

$$\begin{aligned} (E_\pi - E_{\bar{\nu}})^2 - (E_{\bar{\nu}})^2 &= (E_\mu)^2 - (E_{\bar{\nu}})^2 \\ (E_\pi)^2 - 2E_\pi E_{\bar{\nu}} + \cancel{(E_{\bar{\nu}})^2} - \cancel{(E_{\bar{\nu}})^2} &= \left(m_\mu c^2\right)^2 \\ 2E_\pi E_{\bar{\nu}} &= (E_\pi)^2 - \left(m_\mu c^2\right)^2 \\ E_{\bar{\nu}} &= \frac{(E_\pi)^2 - \left(m_\mu c^2\right)^2}{2E_\pi} \end{aligned}$$

Using the energies given in the book (and since the pion energy is its rest mass here),

$$\begin{aligned} E_{\bar{\nu}} &= \frac{(139.5\,\mathrm{MeV})^2 - (105.7\,\mathrm{MeV})^2}{2\,(139.5\,\mathrm{MeV})} \\ &\approx 29.71\,\mathrm{MeV} \end{aligned}$$

30. (a) Electron-positron annihilation releasing 2γ. The exchanged particle is $\mathrm{e}^\pm$ (ambiguous).
    (b) Neutron decay, n (udd) $\to$ p (udu). The charge is carried from ν_μ $(0) \to \mathrm{p}$ $(+1)$. As it's a weak force with $+1$ charge, the particle is W^+, and also since the $\nu_\mu \to \mu^-$ primitive uses a W^+.

31. (a) Since the particles are unchanged, the exchange particle is Z^0.
    (b) Gluon as the exchange is between quarks (strong process).