Ph 135b: Solution Set 3

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For the particles to interconvert they must be antiparticles of each other and so be neutral. They also must have zero baryon and lepton number. We can obviously neglect particles which are their own antiparticles. Hence we must consider neutral mesons with quark content $s\bar{d}$ and $\bar{s}d, c\bar{u}$ and $\bar{c}u, s\bar{b}$ and $\bar{s}b, b\bar{d}$ and $\bar{b}d$ and the yet as unfound mesons $t\bar{u}$ and $\bar{t}u, t\bar{c}$ and $\bar{t}c$.

The neutron does not mix with the anti-neutron as it has non-zero baryon number.

The $K^0\ {}^*$ is not stable and will decay by the strong force into $K\pi$ before it decays to $\bar{K^0}$. Also as K^0 has non-zero spin to form a CP eigenstate we would not get a J_3 eigenstate.

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$$\Gamma = \sigma v |\Psi(0)|^2$$

with $|\Psi(0)|^2 = 1/\pi a^3$ ans $a = 2a_{Bohr}$. Sustituting in the values for m_e, c and $\hbar$ we get

$$\tau = 1.39 \times 10^{-7} s$$

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We are interested only in ratios so we calculate

$$\begin{aligned} \frac{\Gamma(\Psi \to hadrons)}{\Gamma(\Psi \to e^+e^-)} &= \frac{\sigma_{hadrons}}{\sigma_{e^+e^-}} & (1) \\ &= \frac{5}{18}\frac{3}{4}\frac{(\pi^2-9)}{\pi}\frac{\alpha_s^3}{\alpha} & (2) \\ &= 1070\alpha_s^3. & (3) \end{aligned}$$

If we use $\alpha_s = 0.2$ (see footnote on page 165) we get 8.56. The pdg tables give (once we subtract out the decay into virtual photons) 11.92. We can see that

$$\begin{aligned} \frac{\Gamma(\Psi \to \mu^+\mu_)}{\Gamma(\Psi \to e^+e^-)} &= \frac{\sigma_{hadrons}}{\sigma_{e^+e^-}} & (4) \\ &= 1 & (5) \end{aligned}$$

as the lepton mass does not enter into the equation. Again the pdg tables give 0.99.

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Using the formula

$$M(\text{meson}) = m_1 + m_2 + A\frac{(\vec{S_1} \cdot S_2)}{m_1 m_2}$$

with $A = (2m_u/\hbar)^2 160\text{MeV}$ we get

Particle	Formula(Mev)	Observed(MeV)
D_s	1919	1970
D	1711	1864
η_c	2980	2980
Ψ	3007	3097
D^*	1843	2007
D_s^*	2004	2112
B	4978	5279
B_c	6193	6400
B_s^0	5162	5370
Υ	9400	9460

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We have the formula (5.133)

$$\psi(\text{baryon octet}) = \sqrt{2}/3[\psi_1 2(\text{spin})\psi_1 2(\text{flavour}) + \psi_2 3(\text{spin})\psi_2 3(\text{flavour}) + \psi_1 2(\text{spin})\psi_1 3(\text{flavour})]$$

so

$$\begin{aligned}
|\Sigma; 1/21/2\rangle &= \sqrt{2}/3[1/2(\uparrow\downarrow\uparrow - \downarrow\uparrow\uparrow)(us - su)u + 1/2(\uparrow\uparrow\downarrow - \uparrow\downarrow\uparrow)u(us - su) && (6)\\
&\quad +1/2(\uparrow\uparrow\downarrow - \downarrow\uparrow\uparrow)u(us - su)] && (7)\\
&= 1/3\sqrt{2}[uus(2\uparrow\uparrow\downarrow - \uparrow\downarrow\uparrow - \downarrow\uparrow\uparrow) + usu(2\uparrow\downarrow\uparrow - \downarrow\uparrow\uparrow) + suu(2\downarrow\uparrow\uparrow - \uparrow\downarrow\uparrow - \uparrow\uparrow\downarrow)] && (8)\\
&= 1/3\sqrt{2}[2u(\uparrow)u(\uparrow)s(\downarrow) - u(\uparrow)u(\downarrow)s(\uparrow) - u(\downarrow)u(\uparrow)s(\uparrow) + permutations] && (9)
\end{aligned}$$

Similarly for

$$\begin{aligned}
|\Lambda : 1/2, -1/2\rangle &= \sqrt{2}/3[\frac{1}{2}(\uparrow\downarrow\downarrow - \downarrow\uparrow\downarrow)((us - su)d + (ds - sd)u) && (10)\\
&\quad +\frac{1}{2}(-\downarrow\downarrow\uparrow + \downarrow\uparrow\downarrow)(dus - dsu + uds - usd) && (11)\\
&\quad +\frac{1}{2}(-\downarrow\downarrow\uparrow + \uparrow\downarrow\downarrow)(uds - sdu + dus - sud)] && (12)\\
&= \sqrt{2}/6[u(\uparrow)s(\downarrow)d(\downarrow) - 2u(\downarrow)s(\uparrow)d(\downarrow) - u(\downarrow)s(\downarrow)d(\uparrow) + permutations]. && (13)
\end{aligned}$$

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Luminosity

$$\mathcal{L} = N_p \nu n_t L$$

with N_p number of particles per pulse, ν pulse frequency, n_t number density of targets and L the fiducial length. For liquid Hydrogen $\rho = 0.0708$ gcm $^{-3}$ so $n_t = (0.0708)(6 \times 10^{23})\text{cm}^{-3}$ and so

$$\mathcal{L} = 4.2 \times 10^{25}\text{cm}^{-2}\text{s}^{-1}$$

and the integrated luminosity is $\mathcal{L}t = 6.7 \times 10^{32}\text{cm}^{-1}$.