[ Tutorials on Thursdays: 08-10 in C01-148 and 16-18 in U2-135 ]

**Exercise 10.1: Left- and righthanded spinors**
Show that the following identities hold, using the projection operators $P_L = \frac{1}{2}(I_4 - \gamma_5)$ and $P_R = \frac{1}{2}(I_4 + \gamma_5)$:

1. $\bar{\psi}_1 \gamma^\mu P_L \psi_2 = \bar{\psi}_1 P_R \gamma^\mu P_L \psi_2$
2. $\bar{\psi}_1 P_R \gamma^\mu P_L \psi_2 = \bar{\psi}_{1L} \gamma^\mu \psi_{2L}$ with $\psi_{iL} = P_L \psi_i$ for $i = 1, 2$
3. Decomposition of the Dirac-action:

$$\mathcal{L}_D = \bar{\psi}(i\gamma^\mu \partial_\mu - m)\psi = \bar{\psi}_L i\gamma^\mu \partial_\mu \psi_L + \bar{\psi}_R i\gamma^\mu \partial_\mu \psi_R + m(\bar{\psi}_R \psi_L + \bar{\psi}_L \psi_R)$$

**Exercise 10.2: Pion decay**
We assume that electrons (just like neutrinos) are massless. Why can't the decay $\pi^- \to e^- + \bar{\nu}_e$ occur under the weak interaction? [This is an explanation, why the decay mode $\pi^- \to \mu^- + \bar{\nu}_\mu$ with $\Gamma_i/\Gamma = 99,99\%$ is strongly dominating.]

**Exercise 10.3: $K^+$ life time**
Starting from Exercise 5.3, Fermi's model and a dimensional analysis find the order of the life time of the $K^+$-mesons. Compare this to the decay rate found in Exercise 6.1, where we have neglected the strong interaction. [Hint: Consider decays like $K^+ \to \pi^+ + \pi^0$ and neglect $m_\pi$.]

**Exercise 10.4: The weak fine structure constant and $\sigma_{tot}$**
Which value do you obtain for the weak fine structure constant $\alpha_w \equiv g_w^2/(4\pi)$, when you use the values for the Fermi coupling $G_F$ and $W-$boson mass $m_W$ from the lecture and insert it into the relation $G_F = g_w^2/(4\sqrt{2}\, m_W^2)$? Compare this to the corresponding values for $\alpha_{em}$ and $\alpha_s$.

At which energies in the center-of-mass frame are the (approximate) total cross sections for $e^- + e^+ \to q + \bar{q}$ from QED, $\sigma_{tot} \approx \frac{4\pi Q^2 \alpha_{em}^2}{3s}$, and the decay from weak interaction, $\sigma_{tot} \approx \frac{G_F^2 s}{3\pi} \left(\frac{m_Z^2}{s - m_Z^2}\right)^2$, equal? Is the approximation for the former still valid?