HS 16
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Kern- und Teilchenphysik II
Exercise Sheet 1

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Exercise 1: Neutrino oscillations (5.0 Pts.)

With neutrino oscillations, the ”familly lepton numbers” are no longer conserved. This allowes for a process $\mu \to e\gamma$ to happen.

1. Draw a Feynman diagram, where the neutrino oscilations are represented by a blob.
2. In this process you must ”borrow” the necessary to make the virtual W. Accordingly to the uncertainty principle, how soon you must ”repay” the debt? Given the fact that the neutrino oscillations happen over large distance is it likelly to that we can borrow that amount to make the $\mu \to e\gamma$?

Exercise 2: Yukawa Lagrangian (5.0 Pts.)

Give physical interpretation of the Yukawa Lagrangian:

$$\mathcal{L} = \left[i\hbar\bar{\psi}\gamma^{\mu}\partial_{\mu}\psi - m_1\bar{\psi}\psi \right] + \left[\frac{1}{2}\left(\partial_{\mu}\phi\right)\left(\partial^{\mu}\phi\right) - \frac{1}{2}\left(\frac{m_2}{\hbar}\right)^2 \phi^2 \right] - \alpha_Y\bar{\psi}\psi\phi \tag{1}$$

- What are the spins and masses of the particles?
- What are the propagators?
- Draw a Feyman diagram for their interactions and determine the vertex factor.

Exercise 3: CKM matrix (5.0 Pts.)

Show at long as the CKM matrix is unitary, the GIM mechanism works for $n \geq 3$ generations.

- How many independent parameters are there in 3×3 unitary matrix?
- How many independent parameters are there in 3×3 real orthogonal matrix?
- Can you reduce the CKM matrix to real form?

Exercise 4: Generalized Klain-Gordon (5.0 Pts.)

The Klain-Gordon lagrangian for a complex field would look like:

$$\mathcal{L} = \frac{\hbar i}{2}\left[\bar{\psi}\gamma^{\mu}\left(\partial_{\mu}\psi\right) - \left(\partial_{\mu}\bar{\psi}\right)\gamma^{\mu}\psi\right] - m\bar{\psi}\psi \tag{2}$$

Treating both fields as independent deduce the field equations for each and show the fields are consistent.