Teilchenphysik II (Higgs-Physik) (SS 2016)

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Exercises Sheet 03

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Exercise 9: Projection Operators (presence)

In the lecture the projection properties of

$$\psi_L = \frac{1}{2}(1-\gamma^5)\psi$$
$$\psi_R = \frac{1}{2}(1+\gamma^5)\psi$$

have been discussed. It is obvious that $\psi_L + \psi_R = \psi$. Proof the following properties:

a) Both operators are projection operators, i.e.:

$$\left(\frac{1}{2}(1-\gamma^5)\right)^2 = \frac{1}{2}(1-\gamma^5)$$
$$\left(\frac{1}{2}(1+\gamma^5)\right)^2 = \frac{1}{2}(1+\gamma^5)$$

b) Both operators are orthogonal to each other, i.e.:

$$\frac{1}{2}(1+\gamma^5)\cdot\frac{1}{2}(1-\gamma^5) = 0$$

c) The projectors act on the spinors in both directions, i.e.:

$$\overline{e}\gamma^\mu\frac{1}{2}(1-\gamma^5)\nu = \overline{e}_L\gamma^\mu\nu_L$$

d) Proof the relation:

$$\overline{e}\gamma^\mu\partial_\mu e + \overline{\nu}\gamma^\mu\partial_\mu\nu = \overline{e}_L\gamma^\mu\partial_\mu e_L + \overline{e}_R\gamma^\mu\partial_\mu e_R + \overline{\nu}_L\gamma^\mu\partial_\mu\nu_L\,.$$

e) Proof on the other hand the releation:

$$\overline{e}e = \overline{e}_L e_R + \overline{e}_R e_L$$

Exercise 10: Hypercharges of Weak Isospin (presence)

Complete the following table of hypercharges of the weak isospin for electrons and neutrinos: where $Y_{L/R}$ is the hypercharge for left(right-)handed fermion, I_3 is the third component of the weak isospin and Q is the electric charge of the corresponding particle.

$SU(2) \times U(1)$ Hypercharges			
Particle	$Y_{R/L}$	I_3	Q
ν	-1	$+1/2$	
e_L	-1	$-1/2$	
e_R		0	-1

Exercise 11: Allowed Gauge Couplings **(presence)**

Which of the following triple gauge couplings are allowed in the SM?

- γWW
- ZWW
- ZZZ
- $ZZ\gamma$
- $Z\gamma\gamma$;

which of the following quartic gauge couplings are allowed in the SM?

- $WWZ\gamma$
- $WW\gamma\gamma$
- $WWZZ$
- $ZZ\gamma$
- $ZZ\gamma\gamma$;

Exercise 12: Chiral Transformation **(homework)**

The transformation $\chi : \psi \to \gamma^5\psi$ is called *chiral* transformation. It turns e.g. axial vectors into vectors and vice versa.

a) What is the adjoint of the transformed spinor?

b) Proof that $e_L(e_R)$ are *eigentstates* of the chiral transformation with the *eigenvalues* $-1(+1)$.

c) Proof that terms of type $\overline{\psi}\gamma^\mu\partial_\mu\psi$ are covariant under chiral transformations, while terms of type $\overline{\psi}m\psi$ are not. As a consequence the presence of light particles is a small perturbation of a chiral symmetry in the SM Lagrangian density.