

## SM Exercises 9

To be handed in on 24.06.13

1. (45%) Consider a variation of the Standard Model particle content in which the quarks come in different representations: one  $SU(2)_L$  doublet  $Q_L = (u_L, d_L)$ , one  $SU(2)$  singlet  $s_L$ , and  $(u_R, d_R, s_R)$  are all singlets –there are no  $c, b, t$  quarks. The quantum numbers are assigned to maintain the same color and electric charge as in the Standard Model, and electroweak symmetry breaking proceeds in the same way. Write down the Lagrangian for the quark Yukawa interactions. In this model one can write some bare (explicit) mass terms for the quark fields. Find such terms and write out the resulting quark mass matrices after electroweak symmetry breaking. Write the interaction terms of the quarks with the  $Z$  boson in both the interaction and the mass bases (consider only the terms that change when you rotate to the mass basis). Are there tree-level  $Z$  exchange FCNCs in this model?
2. (45%) Consider a two Higgs doublet model in which the Standard Model is extended by an additional Higgs doublet with the opposite hypercharge. For simplicity we will limit ourselves to two quark families. Write down the most general Yukawa interactions for the quarks. Carry out the diagonalization procedure for this model and show that the  $Z$  couplings are still flavor diagonal. Show that in general the Higgs mediates FCNCs.
3. (10%) Consider an extension of the Standard Model with an additional fermion field,  $\chi$ , which is a singlet under the gauge symmetry. Write down the new terms that should be added to the Standard Model Lagrangian in that case. What sector of the SM (gauge, Higgs, quark, lepton) would be affected by such an addition and in what way?