Training problems

1. Write down the whole Lagrangian for the SM in terms of mass eigenstates adopting the unitary gauge. Assume right-handed neutrinos are not present.

2. Adopting the following effective Lagrangian

$$\mathcal{L} = -\frac{G_F}{\sqrt{2}}\left[\bar{\nu}_\mu \gamma^\alpha (1-\gamma_5)\mu\right]\left[\bar{e}\gamma_\alpha (1-\gamma_5)\nu_e\right]$$

   calculate the matrix element squared summed over final spins and averaged over initial spins for the muon decay: $\mu^- \to \nu_\mu e^- \bar{\nu}_e$. Denote the electron and muon momenta by k and p, respectively and use q_1 and q_2 for $\bar{\nu}_e$ and ν_μ momenta, respectively. Assume neutrinos are massless and neglect the electron mass.

3. Derive the Feynman rule vertex factor in the momentum space for the ZZh and W^+W^-h couplings, where h denotes the physical Higgs boson.

4. Derive the Feynman rule vertex factor in the momentum space for hhh and $hhhh$ couplings, where h denotes the physical Higgs boson.

5. Derive the Feynman rule vertex factor in the momentum space for AAW^+W^- and ZZW^+W^- couplings, where A denotes the photon.

6. Derive the Feynman rule vertex factor in the momentum space for AW^+W^- and ZW^+W^- couplings, where A denotes the photon.

7. Calculate the decay width of the Higgs boson h to W^+W^- and ZZ, assuming that h is heavy enough.

8. Calculate the decay width corresponding to top quark decays $t \to Wd_i$, where d_i denote down-type quark of the ith family.