Theoretical Physics

Homework Problems #2
SI2400 Theoretical Particle Physics, 7.5 credits
Spring 2019

Deadline: April 29, 2019 @ 17:00
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1.
- (2 pts) Calculate the cross-section of the process $u_R d_R \to u_R d_R$ in the s-channel considering only the weak interactions.
- (2 pts) Explain why the τ lepton branching ratios are observed to be approximately:
  $\mathrm{BR}(\tau^- \to e^- \nu_\tau \overline{\nu_e})$: $\mathrm{BR}(\tau^- \to \mu^- \nu_\tau \overline{\nu_\mu})$: $\mathrm{BR}(\tau^- \to \nu_\tau + \text{hadrons}) \approx 1 : 1 : 3$.
- (2 pts) In the textbook (Griffiths) the ratio of pion decay rates $\Gamma(\pi^- \to e^- \, \overline{\nu}_e)/\Gamma(\pi^- \to \mu^- \, \overline{\nu}_\mu)$ is shown to be suppressed because of parity violation in weak interactions. What would change if you consider the weak interaction to be vectorial?

2. Z decays:

   Consider the decays of the Z boson in the electroweak theory.

   - (2 pts) Draw the relevant diagram and calculate the partial decay width of the Z boson into a generic pair of fermions (at tree-level). Assume the Z boson is much heavier than any of the fermions.
   - (3 pts) Calculate the total decay rate of the Z into electrically charged particles (experimentally visible in colliders). Use $M_Z = 92$ GeV and $\sin^2\theta_W = 0.23$.
   - (2 pts) Use the value of the total decay width reported by the Particle Data Group (`pdg.lbl.gov`) to calculate the number of neutrinos in the Standard Model.
   - (3 pts) We now consider a hypothetical extension of the Standard Model with one additional generation of leptons with masses much smaller than the Z boson mass. What can you say about this model? What if they are heavier than the Z boson?
   - (2 pts) Repeat the previous part if instead the additional fermions are neutral under all the symmetries of the Standard Model.