

1: (a) Draw lowest-order Feynman diagrams for the reactions

$$(i) e^+e^- \rightarrow c\bar{c}$$

$$(ii) e^+e^- \rightarrow d\bar{d}$$

using only the vertices we saw in the lectures, and neglecting diagrams that contain an intermediate Z boson. This would be appropriate, for example, if $E_{\text{cm}} \ll M_Z$. Label all of the particles and indicate the coupling strengths for all vertices. Note that the reactions here are only parts of more complicated reactions, since at some stage the quarks and antiquarks will transform into mesons and/or baryons.

(b) Assuming that the only difference in probabilities for the two reactions above comes from the different coupling strengths, predict the ratio of cross sections

$$\frac{\sigma(e^+e^- \rightarrow c\bar{c})}{\sigma(e^+e^- \rightarrow d\bar{d})}.$$

2: (a) Draw the lowest-order Feynman diagram for beta decay of a neutron at rest, $n \rightarrow p e^- \bar{\nu}_e$, where the neutron and proton are represented by the appropriate collection of quarks. Label all particles and coupling strengths.

(b) Write down the propagator for the intermediate W boson in (a). What is the value of the W 's virtual mass squared, q^2 , if the neutrino carries off zero energy? (Recall $m_e = 0.000511$ GeV and use the fact that here q^2 is equal to the invariant mass squared of the electron-neutrino system.)

(c) What is the q^2 if the final state proton remains at rest and the electron and antineutrino fly off back-to-back?

For both (b) and (c) you should find $q^2 \ll M_W^2$, and therefore the the propgator can be approximated by $-1/M_W^2$, regardless of how the neutron's energy is shared between the three final state particles.

(d) What would be the effect on the rate of beta decay if the constants of Nature were suddenly to change such that the weak coupling g decreased by a factor of two and the mass of the W boson increased by a factor of three?