Class #10 (Mar. 21) Reading Questions - Cosmic Onion, Chapt. 11 (2nd half) & 12

Summary: The second half of Chapter 11 discusses the cross-generational decay of quarks via the weak interaction. Both quarks and leptons can interconvert within each generation (via the weak interaction) and the probability for such conversion is (almost) identical for each of the three generations. For quarks we also have, with much lower probability, interconversions between the generations as summarized in Fig. 11.4. These different probabilities were first quantified by Cabibbo who described the quarks that participate in the weak interaction as being linear combinations of the original quarks associated with the strong interaction. Thus, instead of seeing a d-quark or an s-quark, the weak interaction sees a superposition of d and s quarks given by d' = d cos(theta_c) + s sin(theta_c) and s' = s cos(theta_c) - d sin(theta_c) where theta_c is the Cabibbo angle. With three generations of quarks three such angles are required while the very small CP violation seen in the weak decays of quarks is encoded with a phase factor delta. A similar issue of different representations of elementary particles under different interactions is also found for the three generations of neutrinos as discussed in Chapter 12. While a "pure" neutrino state is produced in the weak interaction, a free neutrino must be treated as a time-dependent superposition of the three neutrino flavors with the rate of interconversion between the flavors being set by their mass differences. Thus, such neutrino oscillations, which are observed experimentally, require that the neutrinos have mass.

Questions:

1. If we just consider the first two generations of quarks, the probability for cross-generational decay is 1/25. Explain how this probability is related to the Cabibbo angle. What value does this give for theta_c?

2. Why is the CP violation stronger for the B-meson than the K-meson?

3. Explain how neutrino mass is involved in neutrino oscillations.

4. Both the super-Kamiokande and the SNO neutrino detectors measure Cerenkov radiation. Explain how this type of radiation is produced.

5. Explain why massless neutrinos can all be left-handed whereas neutrinos with mass should come in both left and right handed versions.

Your Question: Please give a well-formulated question that you have regarding the material covered in this reading assignment.