

Final Exam (129A), Dec 13, 5–8 pm

1. Explain the branching fractions of the W -boson. [15]
2. A very high-energy cosmic ray proton would absorb the cosmic-microwave background photons to become a Delta resonance, which quickly decays into a nucleon and a pion, thereby losing its energy. Assuming all CMBR photons have the energy $E = kT$, what is the maximum proton energy for this not to happen? (There is a puzzling report that we see cosmic rays above this so-called GZK cutoff.) [10]
3. KamLAND experiment reported 54 reactor anti-electron-neutrino event for 86.8 ± 5.6 events (5.6 is the systematic error) expected without neutrino oscillation. Assume all reactors are at the distance of 180 km and the neutrino energy of $E_\nu \sim 3$ MeV. (1) What is the reaction used to detect reactor anti-electro-neutrino? [5] (2) If Δm^2 is relatively high and the oscillation is averaged out, what is the preferred value of $\sin^2 2\theta$ with statistical and systematic errors? [5] (3) In order for a sizable oscillation effect to be present as observed, estimate what the minimum value of Δm^2 is in eV^2 . [5]
4. 21cm line of hydrogen hyperfine transition is important in measuring the rotation curve of galaxies. In order to see emission lines, excited states must be present. Why are there excited hyperfine states in the cold space? [10]
5. Existence of matter but no antimatter in Universe suggests that the baryon and lepton numbers are actually violated, and hence proton may decay. Grand unified theories indeed predict it. List five possible decay modes of the proton consistent with all other conservation laws. [15]
6. Using K resonances, identify states on the leading Regge trajectory [5], obtain the Regge slope [5], and the force between the quark and the anti-quark in Newton [5].
7. Experiments at LEP-II e^+e^- collider searched for the Higgs boson, found a hint, but finished with a lower bound of 114.4 GeV (95% CL). Draw the Feynman diagram which could have been relevant for the Higgs boson production at LEP-II. [5]
8. Using the Friedmann equation $\left(\frac{\dot{R}}{R}\right)^2 = \frac{8\pi}{3}G_N\rho$, the first law of thermodynamics $d(\rho R^3) = -pd(R^3)$, and the equation of state $p = w\rho$, determine the evolution of the scale parameter $R(t)$ for Universe dominated by relativistic matter $w = 1/3$, non-relativistic matter $w = 0$, and the cosmological constant $w = -1$. Show that the Universe accelerates $\ddot{R} > 0$ only for the last case. [15]