Nuclear Physics - Problem Set 7 – Due Tuesday, 11/6

Note: For the following problems, we should follow the nomenclature of Povh et al., where $g_V$ and $g_A$ include the Fermi constant and the Cabbibo factors (see Eqs. 16-49-16.50). Hence, the dimensionless axial coupling that appears in Problem 1 is really the ratio $g_A/g_V$. Note that $c_V = +1$. $c_A = -1$, but I will ignore any sign inconsistencies.

**Problem 1)**

a) Again starting with the wave function for a proton given in Povh et al., Eq. 16.4 page 262 or in Wong, Eq. 2-46 p. 48 or my HUGS writeup, calculate the transition matrix element for the Gamov-Teller transition in neutron beta decay: $g_A/g_V = \langle p | \Sigma q \sigma_A(q) I^\tau(q) | n \rangle$. ($I^\tau(q)$ turns a down quark into an up quark and yields zero if applied to an up quark.) Show that your answer agrees with the relationship $g_A/g_V = \Delta u(\text{proton}) - \Delta d(\text{proton})$ (quote the results from last weeks HW assignment). Ignore any difference in sign.

b) Check the Bjorken sum rule, i.e. show that your result for the difference $\Gamma_1^p - \Gamma_1^n$ from last week agrees with the prediction by Bjorken, $\Gamma_1^p - \Gamma_1^n = g_A/g_V/6$.

**Problem 2)**

Follow Chapter 16.6 (“Semileptonic Baryon Decays”) in the book by Povh et al. to derive the lifetime $\tau_n$ of the neutron in terms of the parameters $g_V$ and $g_A$. Note that $E_0$ refers to the total energy (mass) difference between the neutron and the proton, not that between a neutron and a hydrogen atom. You may begin with Eq. 16.59 (p. 278).

a) Determine $g_V = G_F \cos \theta_C$ and $g_A = g_A/g_V \cdot g_V$ using your result from Problem 1. With these constants, calculate the result for Eq. 16.59.

b) Compare your result with the measured lifetime. Repeat if you replace $g_A/g_V$ with the “true” measured value for the axial coupling, $g_A/g_V = 1.26$. 
