511 Nuclear Physics University of South Carolina **Spring 24**

Homework Set 2 Instructor: Ralf W. Gothe **1/23/24**

2.1) **Gravitational versus Coulomb Forces**

2.1.1) [3] How many times is the Coulomb force in a hydrogen atom stronger than the gravitational force? Use $\alpha = \frac{e^2}{4\pi\epsilon_0\hbar c}$ and $G_N = \frac{\hbar c}{m^2_{\text{Planck}}}$.

2.1.2) [4] You want to solve your homework problems with another student. Both of you weigh $100\,kg$, can pull on a rope with $1000\,N$ and are made up of $100\,\%$ water, all quite reasonable assumptions. What is the minimum distance you can stabilize, if only $0.1\,\%$ of the water molecules carry one extra charge e and both of you hold on to a massless, infinitely long rope?

2.2) **Determining Masses from Nuclear Reactions**

2.2.1) [3] A thermal neutron is captured by a hydrogen atom creating a deuterium atom and emitting a photon. $2.224\,MeV$ is the measured energy of the emitted photon, but the mass of deuterium and the binding energy of the proton and the neutron in the deuteron are not known. Calculate the binding energy under the assumption that $M_D = m_p + m_n + m_e$ and calculate the next order correction to it.

2.3) **Isospin symmetry**

2.3.1) [4] One could naively imagine that the three nucleons in the ^3H and ^3He nuclei are rigid spheres. How far are the protons in ^3He separated, if one solely attributes the difference in the binding energies of these two nuclei to the electrostatic repulsion of the protons? Use that the maximum energy of the electron in the β^--decay of ^3H is $18.6\,keV$.

2.4) **Mass Formula**

2.4.1) **[GS]** [5] Isaac Asimov in his novel *The Gods Themselves* describes a universe where the stablest nuclide with $A = 186$ is not $^{186}_{74}W$ but rather $^{186}_{94}Pu$. This is claimed to be a consequence of the ratio of the strengths of the strong and electromagnetic interactions being different to that in our universe. Assume that only the electromagnetic coupling constant α differs and that both the strong interaction and the nucleon masses are unchanged. How large must α be so that $^{186}_{82}Pb$, $^{186}_{88}Ra$ and $^{186}_{94}Pu$ are stable?