Physics 4440, Mid Term Exam, Spring 2019

prob.1 quarks, mesons and baryons

a) A pion and a proton are both made of quarks which are fermions. The pion has a ground state spin of J=0 and the proton's spin is J = 1/2. Why are the spins so different if both are made of quarks?

b) You are an editor of Physical Review C and an author sends in a paper stating that his group has discovered a new meson of spin J=5/2. Are you going to accept his paper? Explain your decision.

c) Consider the following processes and state based on the conservation laws whether or not they are allowed. Assume the incident anti proton and proton are colliding with 100 GeV of energy each.
i) $p + \overline{p} \rightarrow n + \pi^0$
ii) $p + \overline{p} \rightarrow W^+ + W^-$
iii) $p + \overline{p} \rightarrow e^+ + e^- + \nu_e$

d) If the pion mass were about 70 MeV instead of around 139 MeV what effect, if any, would you expect this to have on the nucleon-nucleon force?

prob.2 Nuclear sizes and nuclear masses

a) The reaction $^4He + ^{12}C \rightarrow ^{16}O + \gamma$ is of great astrophysical importance. How much energy is released in this reaction if we can ignore the initial kinetic energies of the colliding nuclei? Use the mass tables.

b) The binding energy per nucleon, B/A $\approx = 8$ MeV, for A greater than about 40 tells us something about the range of the nucleon-nucleon interaction. Is this a short range or long range interaction? How does it compare to the Coulomb interaction?

c) Figure 4.5 in our text for the A = 64 nuclei shows two curves for Z versus relative atomic mass. Why are there two curves?

d)The Born approximation cross section formula given in problem 4.2(b) calculates the cross section for an incident electron energy of E and a three momentum transfer , $\hbar q = \vec{p} - \vec{p'}$, where $\vec{p}$ and $\vec{p'}$ are the incident and scattered electron's momenta. The parameter q in this equation is given in 4.2(a). If the nucleus is assumed to be a uniformly charged sphere of radius R show that

$$\int dr^3 \rho(r) exp(i\vec{q} \cdot \vec{r}) = 3(qRcos(qR) - sin(qR))/(qR)^3$$

Hint: Use the direction of $\vec{q}$ as the z-axis in the integration.

prob.3 nuclear structure models

Classify these three nuclei, ^{41}Ca, ^{112}Cd, ^{232}Th, according to an appropriate model, based on the ground state and the structure of the low lying excited states. Explain the basis for your classifications.

prob.4 alpha decay

Calculate the mean life and half life of alpha decay for ^{228}Th and ^{232}Th. Compare to their measured half lives. You must use the mass tables for this.

prob.5 Shell Model Nuclear Structure

Consider the shell model predictions for the ground state and low lying excited states of ^{210}Bi.

a) What proton and neutron orbitals are relevant for the ground state and low lying states?

b) Based on these orbitals what spins and parities, J^{π} do you expect to find for the ground state and low lying states?

c) Compare your shell model predictions from part b) to the known level structure of ^{210}Bi.

Note: You will need the shell model orbitals from p. 62 of the text and information from the National Nuclear Data Center.