Nuclear physics

Midsession test 2012

Time allowed one hour.
All questions below need to be addressed.
If math presents a difficulty then give exlanation in plain English.
Calculators would not be required.

Formulas and data which may be useful

$$1 \text{ fm} = 10^{-15}\, m \tag{0.1}$$

$$1 \text{ MeV} = \frac{197}{1 \text{ fm}} \tag{0.2}$$

$$r = r_0 A^{1/3}, \quad r_0 = 1.2 \text{ fm} \tag{0.3}$$

Bohr radius

$$a_B \approx 0.5\, 10^{-10}\, m = 0.5\, 10^5 \text{ fm} \tag{0.4}$$

Binding energy of the deuteron

$$E_{Bd} \approx 2.2 \text{ MeV} \tag{0.5}$$

Question 1 (40%) Nuclear structure
Give a brief, qualitative description of the nuclear structure. In particular

- outline the physical origins of nuclear forces
- present the typical distances (in fm) at which these forces are effective and explain which fundamental parameter regulates this distance
- indicate at which distances the nuclear forces are attractive and where they are repulsive
- discuss how the attraction and repulsion of the nuclear forces manyfests itself in nuclear properties; how strongly the nuclear density varies in nuclei ?
- estimate the typical density of nucleons in nuclei (fm^{-3}) and compare it with the typical density of atoms in condense matter (accurate calculations are not required, give only an estimate of the order of magnitute)

Question 2 (30%) Nuclear reactions
Consider the neutron - proton collision which results in the creation of the deuteron with emission of a photon

$$n + p \to d + \gamma$$

Assume that in the center of mass the kinetic energies of the proton and neutron are low, K_p, $K_n \ll 1$ MeV.

- Find the wavelength of the emitted photon with, say, 10% accuracy (which does not need calculators). Argue whether this photo - process should or should not be described as the E1 transition ?

Question 3 (30%) Symmetries

Consider the four known fundamental interactions, strong , weak, electromagnetic and gravitational interactions.

Indicate which of them conserve and which break each one of the following physical quantities

- angular momentum
- parity
- isotopic spin

Consider two neutrons, which exist in some nucleus above its closed nuclear shells. Remeber that such pair developes a strong binding and consiquently can be treated as a bound state, pair of neutrons (compare Cooper's pairs in condense matter).

Presume that the relative orbital momentum of neutrons in this pare is zero, $L = 0$ (the most *common* binding) .

- find the spin S of this pair
- find the isotopic spin I and its projection I_3 for the pair