
Nuclear physics

Midsession test 2012

Time allowed one hour.

All questions below need to be addressed.

If math presents a difficulty then give explanation in plain English.

Calculators would not be required.

Formulas and data which may be useful

$$1 \text{ fm} = 10^{-15} \text{ m} \quad (0.1)$$

$$1 \text{ MeV} = \frac{197}{1 \text{ fm}} \quad (0.2)$$

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

Bohr radius

$$a_B \approx 0.5 \cdot 10^{-10} \text{ m} = 0.5 \cdot 10^5 \text{ fm} \quad (0.4)$$

Binding energy of the deuteron

$$E_{B,d} \approx 2.2 \text{ MeV} \quad (0.5)$$

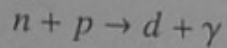
Question 1 (40%) Nuclear structure

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 manifests 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 magnitude)

Question 2 (30%) Nuclear reactions

Consider the neutron - proton collision which results in the creation of the deuteron with emission of a photon



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

- 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. Remember that such pair develops a strong binding and consequently can be treated as a bound state, pair of neutrons (compare Cooper's pairs in condensed matter).

Presume that the relative orbital momentum of neutrons in this pair 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