THE UNIVERSITY OF NEW SOUTH WALES
SCHOOL OF PHYSICS

Nuclear Physics
2014
Midsession test

University - approved calculators may be used.
Both questions below need to be answered.
They have same marking value 50%.
If math presents a problem, try to present the idea in plain English.

- **Question 1 (50 %) Nuclear structure and nuclear forces**

  Present the few fundamental for nuclear physics parameters, which can be used for qualitative description of the nuclear structure. Using these parameters

  (a) Provide an estimate for the typical distance (fm) at which the nuclear forces are effective and explain which fundamental parameters regulate this distance

  (b) Give an estimate for typical kinetic and potential energies (MeV) of nucleons in nuclei; estimate also the force between nucleons (MeV/fm)

  (c) Compare your estimates for nuclear energies with typical atomic energies; explain very briefly, in simple qualitative terms the physical reasons, which make them so different

  (d) Estimate a typical velocity of nucleons inside nuclei and compare it with velocities of electrons in metals

  (e) Provide an estimate for typical Coulomb energy in nuclei; explain which nuclear properties ensure that it is negligible in some nuclei while essential in others

- **Question 2 (50 %) Simple nuclear models**

  (a) Outline very briefly the basic physical idea of the Fermi gas model

  (b) Using the Fermi model and the fact that $r_{nucleus} = 1.2\,A^{1/3}$ fm derive an expression for the Fermi energy of protons in a nucleus with charge Z; present also (do not derive) the avarage energy per proton (keep attention on important physical paramaters, numerical coefficients are of lesser significance);

  (c) Provide a definition for the binding energy of a nucleus

  (d) Present Weizsäcker's formula, which describes the binding energy within the liquid drop model

  (e) Assume that one is contemplating an application of this formula to a nuclear star and needs therefore to include the gravitational energy of the star in the formula. Present dependence of the necessary additional term to the formula on A and Z, as well as on neutron and proton masses m_p, m_n and gravitational constant G (the parameters as well as the sign are important, while numerical coefficient can be omitted).

$$\frac{G m_1 m_2}{A^{1/3}}$$

$$V_g = \frac{G\left(Z m_p + (A-Z) m_n\right)}{A^{1/3}}$$