PHY401: Nuclear and Particle Physics

Midsem - 1 (MS21: Physics)

15:30 - 16:30 on 9^{th} September 2024

1.0 hours 25 marks

$m_e = 0.000549$ amu	$m_{{}^{1}_{1}\mathrm{H}} = 1.00784$ amu	$m_{n} = 1.008665$ amu
$m_{{}^{16}_{8}\mathrm{O}} = 15.9949$ amu	$m_p = 1.007276$ amu	$1\text{amu} = 931.5 MeV$
1 amu $= 1.66054 \times 10^{-27}$ Kg	$1eV = 1.602 \times 10^{-19} J$	$m_{{}^{4}_{4}\mathrm{He}} = 4.0026$ amu
$r_o = 1.2\ fm$		

Answer all the questions.
Attempt all the sub-parts of a question at one place.

Q 1: Derive that 1 *amu* is equivalent to 0.9315 *GeV* using natural units. Mathematically show that a vehicle traveling at 90 km/h does not require relativistic corrections, while a meteorite moving at 195000 km/s does. *(2.5 + 2.5 marks)*

Q 2: Derive the expression for the radius of nucleus and find the same for ${}^{56}_{26}\mathrm{Fe}$ & ${}^{3}_{1}\mathrm{H}$. Calculate the nuclear *Matter-density* and *Charge-density* of ${}^{208}_{82}\mathrm{Pb}$ atom. *(3 + 1.5 + 1.5 marks)*

Q 3: Derive the distance of the closest approach for a 5 MeV $\alpha-$particle moving in the line-of-sight of a ${}^{201}_{80}\mathrm{Hg}$ nucleus with no electron? *(5 marks)*

Q 4: Derive the expression for nuclear-binding energy of nucleus and estimate the value of the same for ${}^{16}_{8}\mathrm{O}$. Calculate the ratio of hydrogen ionization-energy to the nuclear-binding energy per nucleon of ${}^{16}_{8}\mathrm{O}$. *(3 + 1 marks)*

Q 5: Write down the semi-empirical mass formula? Derive and explain the reasoning behind the (a) volume contribution (b) surface contribution, and (c) Coulomb term contribution. *(0.5 + 1.0 + 1.5 + 2 marks)*

2. Write down the Bravais lattice for a FCC crystal. Compute the reciprocal lattice. Does this match with any other lattice in real space ? **(10)**

3. A lattice site with an atom is described by a potential $U(x)$. Assume some particles scatter of this potential with wave vector $\mathbf{Q}$. Write down an expression for the differential scattering cross section using Born approximation . Now assume the potential is shifted to $x + a$. Write done the expression for the new what will be the expression for the new cross section. **(10)**

4. Assume a free electron gas is confined to 2D with a charge density n per unit area . Write down the expression for Density of States. Calculate the Fermi energy in terms of charge density n and other relevant fundamental constants.

(10)