(This Question paper contains 2 printed page) Roll No.....

Sr. No. of questions Paper : 8122

Name of Course: B.Sc. (Hons.) Physics_NEP: UGCF-2022

Semester: VIII- Semester (DSE Paper)

Name of the Paper: Nuclear and Particle Physics

Unique Paper Code: 2223010042

Duration: 3 Hours **Maximum marks: 90**

(Write your Roll No. on the top immediately on receipt of this question paper).

Attempt five questions in all.

Question No. 1 is compulsory.

Use of scientific calculators is allowed.

Q1. Attempt any six of the following: (6x3=18)

(a) Show that the density of nuclear matter is independent of its mass number.

(b) The radius of a $^{64}_{29}Cu$ nucleus is measured to be 4.8 x 10^{-13} cm. Estimate the radius of $^{27}_{12}Mg$ nucleus.

(c) Assuming that in a nucleus N = Z = A/2, calculate the Fermi momentum and well depth (Fermi Nuclear model).

(d) Name and explain the physical quantities that are not necessarily conserved in a nuclear reaction.

(e) Define Cherenkov radiation and explain the specific physical condition required for its production.

(f) Give the meaning of each term in one sentence: Boson, Fermion, Hadron, Lepton and Baryon. Give one example of a particle for each of the above. Which of the above names is, and which is not, applicable to the photon and gluon?

(g) For the following list of particles *{v, W, g, c, H, τ}* -denoted by the symbol- identify their name and the following quantum numbers : (i) Spin (ii) Charge (iii) Baryon number (iv) Color charge (Yes/No) (v) Weak Isospin (vi) Weak Hypercharge and (vii) Lepton number

Q2. (a) Draw a schematic diagram of the single particle energy levels in a shell model including the effect of spin-orbit coupling. Show how it explains magic numbers in nuclei. (12)

(b) Predict the spin and parity of ground states of the following nuclei on the basis of

Shell Model: $^{17}_{8}O$, $^{7}_{3}Li$ and $^{10}_{5}B$ (6)

Q3. (a) How were the limitations of nuclear shell model rectified by collective model? Menton the achievements of collective model. (10)

(b) Discuss magnetic moment of the nucleus. (4)

(c) Find the nuclear density of ^{235}U, if R_0= 1.2 fm (4)

Q4. (a) Explain the term's nuclear reaction cross-section and differential cross section. Derive an expression for nuclear reaction cross-section. Has the nuclear reaction cross-section any relation to the target area? (10)

(b) What are stripping and pickup reactions with example? (4)

(c) What is Rutherford Scattering? (4)

Q5. (a) Explain the interaction of gamma rays with matter via the processes of photoelectric effect, Compton scattering and pair production. Compare these processes in terms of their dependence on photon energy and atomic number and indicate the energy ranges in which each process is dominant. (10)

(b) Explain how neutrons interact with matter. Why do neutrons exhibit greater penetrating power compared to charged particles? (4)

(c) A gamma ray photon of energy 1 MeV undergoes Compton scattering. Calculate the maximum kinetic energy imparted to the recoil electron. (4)

Q6. (a) Within the Quark Model, the baryon Δ^{++} consists of three identical up quarks (*uuu*), with spin $S = 3/2$ and orbital angular momentum $L = 0$. Show that the spatial, spin, and flavor wave-functions are each symmetric under exchange of quarks, so that the total wave-function

$$\Psi_{space} \cdot \Psi_{spin} \cdot \Psi_{flavor}$$

is symmetric. Explain why this violates the Pauli exclusion principle for fermions, and how introducing color resolves this contradiction. (10)

(b) For a general $2 \rightarrow 2$ process: $a+b \rightarrow c+d$, define the Mandelstam variables s, t, u as follows:

$$s = (p_1 + p_2)^2, \quad t = (p_1 - p_3)^2, \quad \& \quad u = (p_1 - p_4)^2.$$

Show that:, $s+t+u = \sum_i m_i^2$ where $i \in \{a, b, c, d\}$.

Also, Show that in the ultra-relativistic limit

$$(s \gg m_i^2, \forall i), \; s \simeq 4E^2$$ (8)