Registration No.: | | | | | | | | | | |

Total Number of Pages: 02 **Course: M.Sc.I**

Sub_Code: FPYC902

9th Semester Regular Examination: 2024-25

SUBJECT: Nuclear and Particle Physics

BRANCH(S): M.Sc.I(AP)

Time: 3 Hours

Max Marks: 70

Q.Code: R058

Answer Question No.1 (Part-I) which is compulsory, any five from rest (Part-II)

The figures in the right-hand margin indicate marks.

Part-I

Q1 **Answer the following questions:** **(2 x 10)**

a) Explain how nucleon separation energy helps to determine the stability of a nucleus.

b) Given the binding energies of two mirror nuclei, ^{3}H (tritium, Z = 1, N = 2) and ^{3}He (helium-3, Z = 2, N = 1), which are 8.482 MeV and 7.718 MeV respectively, calculate the difference in binding energy per nucleon and discuss if this supports charge independence of nuclear force?

c) Why do lighter elements have a roughly equal number of protons and neutrons on the beta stability line, while heavier elements do not?

d) What physical information can be derived from the Hofstadter form factor?

e) Why is the active decay law considering a statistical law? The activity of a radioactive sample decreases from 500 Bq to 125 Bq in 6 hours. Calculate the half-life of the substance using the active decay law.

f) Explain the role of excitation energy in the compound nucleus theory.

g) How does the wavefunction symmetry of a system differ for fermions and bosons? Determine whether a particle with spin 3/2 is a fermion or a boson.

h) Why is hypercharge conserved in strong interactions? Determine the hypercharge of a Λ particle ($Q = 0$, $I_3 = 0$).

i) What is the physical significance of the center of the meson octet in the SU (3) diagram?

j) Explain how the baryon number (B) is conserved in the baryon octet. Determine the isospin third component (I_3) of the K^0 meson ($Q = 0$, $Y = +1$).

Part-II

Q2 **Long Answer Type Questions (Answer Any five)**

a) Define the electric quadrupole moment and magnetic dipole moment of a nucleus. Explain their physical significance in terms of nuclear shape and spin. **(5)**

b) Describe the process of nuclear de-excitation. How are the lifetimes of excited states determined experimentally? A nucleus transitions from an excited state with energy E_1 = 2 MeV to the ground state by emitting a gamma photon. Calculate the wavelength of the emitted photon and discuss the significance of such transitions. **(5)**

Q3 **a)** Describe how isospin symmetry affects the interactions between nucleons in a nucleus. **(3)**

b) Define the nuclear form factor and explain its significance in the context of electron scattering experiments. How is the form factor related to the spatial distribution of charge inside the nucleus? **(7)**

Q4 **a)** Explain Gamow's theory of alpha decay. Derive the expression for the decay constant using the quantum mechanical tunneling concept. Discuss the role of the Coulomb barrier in the process of alpha emission. **(7)**

b) A particle undergoes two possible decay modes: Mode 1 with a branching ratio of 0.6, and Mode 2 with a branching ratio of 0.4. If the total decay rate of the particle is $\lambda = 10^6\ s^{-1}$, calculate the decay rates for Mode 1 and Mode 2. **(3)**

Q5 **a)** Explain the Breit-Wigner formula for resonance scattering. Discuss the significance of the resonance energy (E_R) and the resonance width (Γ) in shaping the scattering cross-section. **(7)**

b) For a transition in an atom, the initial state has n = 3 and l = 2, and the final state has $n' = 2$ and $l' = 1$. Calculate whether the transition is allowed based on the selection rules for n, l, and m_l. **(3)**

Q6 **a)** Describe the classification of elementary particles based on their interactions and quantum numbers. Discuss how quarks and leptons are grouped, and explain the role of gauge bosons in mediating fundamental forces. **(6)**

b) In the context of SU (3) symmetry, explain the significance of the quark content of baryons like the proton, neutron, and the Lambda baryon. How does SU (3) symmetry predict the properties of these particles? **(4)**

Q7 **a)** Using the example of the pion decay, explain how the spin and parity of the pion are experimentally determined. What role does the conservation of angular momentum play in this process? **(7)**

b) Consider a system consisting of a pair of quarks: an up quark (u) and a down quark (d). The spin of each quark is 1/2. If the up quark is in the +1/2 spin state and the down quark is in the −1/2 state, calculate the total spin of this quark pair. **(3)**

Q8 **a)** Explain how the shell model accounts for the energy levels in a nucleus. Using the shell model, explain why nuclei with magic numbers of protons or neutrons are more stable than others. **(7)**

b) Why are the particles in the baryon octet stable or quasi-stable compared to those in the baryon decuplet? **(3)**