BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(END SEMESTER EXAMINATION)

CLASS: Int.M.Sc/ M.Sc **SEMESTER : IX/III**
BRANCH: PHYSICS **SESSION : MO/2025**

SUBJECT: PH501 NUCLEAR AND PARTICLE PHYSICS

TIME: 3 Hours **FULL MARKS: 50**

INSTRUCTIONS:
1. The question paper contains 5 questions each of 10 marks and total 50 marks.
2. Attempt all questions.
3. The missing data, if any, may be assumed suitably.
***4*. Before attempting the question paper, be sure that you have got the correct question paper.**
5. Tables/Data hand book/Graph paper etc. to be supplied to the candidates in the examination hall.

			CO	BL
Q.1(a)	What are magic numbers ? List the evidence in favour of the existence of a shell structure in the nucleus.	[5]	1	1,2
Q.1(b)	Mirror nuclei are pairs of nuclei that have number of protons (Z) and number of neutrons (N = A - Z) that are mutually inter-changeable (i.e. $N_1 = Z_2$ and $Z_1 = N_2$). Using the Semi-Empirical mass formula: $E^{Binding} = [a_1 A - a_2 A^{2/3} - a_3 Z(Z-1)A^{-1/3} - a_4 (A-2Z)^2 A^{-1} \pm (a_5 A^{-3/4})]$. Compute the mass difference between 2 mirror nuclei which have $\|N_i - Z_i\| = 1$ (where, i = 1,2) and the same odd mass number A.	[5]	1	3
Q.2(a)	Derive the ground state wave-function for the deuteron by solving the Schrödinger equation assuming a rectangular potential well of depth V_0 for the nuclear potential. $V(r) = -V_0 \; ; \; \|r\| \leq b$ $V(r) = 0 \; ; \; \|r\| > b$ Draw the radial part of the wave-function as a function of r.	[5]	2	1,2
Q.2(b)	If $\overrightarrow{s_p}$ and $\overrightarrow{s_n}$ are spin angular momenta of proton and neutron respectively. Then compute the following for the deuteron (in units of $\hbar^2$): $\langle(\overrightarrow{S_m})^2\rangle = \langle(\overrightarrow{s_p} - \overrightarrow{s_n})^2\rangle$	[5]	2	3
Q.3(a)	Briefly describe the differences b/w np, pp and nn scattering at low energies. `	[5]	3	1,2
Q.3(b)	Using the theory of partial wave analysis, compute the total scattering cross-section (σ^l_s) for the case of elastic pp scattering in terms of phase-shift (δ_l) for the l^{th} partial wave given incident wave vector k. If this cross-section is measured to be 3.2 barn, and the incident proton beam energy is 5 MeV, Compute: (i) Phase-shift (δ_l) for s-wave scattering in radians. (ii) Fermi scattering length (a) in fm.	[5]	3	1,3
Q.4(a)	What are the various mechanisms of energy loss for an electron/positron as it traverses through a medium ? Which is the dominant one and Why ?	[5]	4	1,2
Q.4(b)	(i) What is the critical energy ? Determine it for Pb^{208} and Cu^{64} in MeV. (ii) Define the terms: Radiation length and Moliere radius.Compute them for Pb^{208}.	[5]	4	1,3
Q.5(a)	Briefly describe the fundamental interactions/forces of nature. List the particles of the Standard Model and their basic properties (e.g. mass, charge, spin etc..).	[5]	5	1,2
Q.5(b)	Use the Gell-Mann Nishijima relation and the quark model to find the quantum numbers: Electric charge (Q), Baryon number (B), Strangeness number (S), and Iso-spin z-component I_3 for the following quark combinations: (i) uds (ii) uus (iii) uud (iv) uss (v) $u\bar{s}$ What particles do these combinations represent ?	[5]	5	3

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