BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(END SEMESTER EXAMINATION MO2022)

CLASS: MSC / IMSC **SEMESTER : III / IX**
BRANCH: PHYSICS **SESSION : MO2022**

SUBJECT: PH501 NUCLEAR AND PARTICLE PHYSICS

TIME: 03 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*. Tables/Data handbook/Graph paper etc., if applicable, will be supplied to the candidates**

Q.1(a) Define Binding Energy of a nucleus. Explain the difference between: Isotopes, Isobars and Isotones. [2]

Q.1(b) What are magic numbers ? What are the evidences of the existence of a shell structure in the nucleus ? Give a brief account of the shell model of the nucleus that predicts the magic numbers. [5]

Q.1(c) Mirror nuclei are pairs of nuclei that have number of protons (**Z**) and number of neutrons (**N = A - Z**) that are mutually interchangeable (i.e. $N_1 = Z_2$ and $Z_1 = N_2$). Using the Semi-Empirical mass formula: $E^{Binding} = [a_1 A - a_2 A^{2/3} - a_3 Z(Z-1)A^{-1/3} - a_4 (A-2Z)^2 A^{-1} \pm (-a_5 A^{-3/4})]$, where $a_5 = 0$ for odd **A**, 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**. [3]

Q.2(a) What are the main properties of the inter-nucleon interaction between the proton and the neutron inside the deutron ? Is it a fundamental interaction/force of nature ? [2]

Q.2(b) Calculate the depth of the deutron (rectangular) potential well (V_0^{min}) if the equilibrium separation b/w the nucleons is: [3]
(i) 0.5 fm
(ii) 4.0 fm

Q.2(c) If $\vec{s_p}$ and $\vec{s_n}$ are spin angular momenta of proton and neutron respectively. Then compute the following for the deutron (in units of $\hbar^2$): [5]

$$\langle(\vec{S_m})^2\rangle = \langle(\vec{s_p} - \vec{s_n})^2\rangle$$

Q.3(a) Define singlet and triplet states in terms of np scattering. What are the probabilities for the np system to be in singlet and triplet states ? [2]

Q.3(b) Briefly describe the differences b/w np, pp and nn scattering at low energies. [3]

Q.3(c) The total proton-proton scattering cross-section (σ) was measured to be 3.2 barn. [5]
(i) Calculate the phase shift (δ_0) in radians for incident proton beam energy of 5 MeV.
(ii) Compute the scattering length (**a**) in fm.

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 ? [2]

Q.4(b) (i) What is the critical energy ? Determine it for Pb^{208} and Cu^{64} in MeV. [3]
(ii) Define the terms: Radiation length and Moliere radius. Compute them for Pb^{208}.

Q.4(c) (i) If the range of 1 MeV proton in Fe^{56} is 5.44×10^{-3} gm/cm^2, what will be the range of the same particle in Al^{27} ? [5]
(ii) If the ranges of a 10 MeV α-particle in Si^{28} and O^{16} are: 2.68×10^{-3} cm and 9.45 cm respectively, what will be its range (in cm) inside silica (SiO_2) ?
(Given: $\rho^{Si} = 2.33$ gm/cm^3, $\rho^{Si} = 0.001429$ gm/cm^3, $\rho^{Silica} = 2.65$ gm/cm^3)

Q.5(a) Define an elementary particle. List all the elementary particles of the Standard Model and the categories they fall into. [2]

Q.5(b) Briefly describe the fundamental interactions/forces of nature. [3]

Q.5(c) Use the Gell-Mann Nishijima relation and the quark model to find the quantum numbers: [5]
Q, Baryon number, Strangeness number, and I_3 for the following quark combinations:
(i) $u\bar{d}s$
(ii) uus
(iii) $\bar{u}\bar{u}\bar{d}$
(iv) uss
(v) $u\bar{s}$
What particles do these combinations represent ?

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