MPH-017

ASSIGNMENT BOOKLET

M.Sc. (Physics) Programme
(MSCPH)

NUCLEAR AND PARTICLE PHYSICS

Valid from 1st January, 2025 to 31st December, 2025

School of Sciences
Indira Gandhi National Open University
Maidan Garhi, New Delhi-110068
(2025)

Dear Student,

Please read the section on assignments in the Programme Guide for M.Sc. (Physics) before attempting this Tutor Marked Assignment. A weightage of 30 per cent, as you are aware, has been earmarked for continuous evaluation, **which would consist of one tutor-marked assignment** for this course. The assignment is in this booklet, and it consists of two parts: Part A and Part B. The total marks of both parts are 100, of which at least 40% are needed to pass.

Instructions for Formatting Your Assignments

Before attempting the assignment, please read the following instructions carefully:

1) On top of the first page of your answer sheet, please write the details exactly in the following format:

ROLL NO.: ……..…

NAME: ……..…

ADDRESS: …….

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COURSE CODE:…….

COURSE TITLE: ……

ASSIGNMENT CODE: ……..

STUDY CENTRE: …….. **DATE:** …….....

PLEASE FOLLOW THE ABOVE FORMAT STRICTLY TO FACILITATE EVALUATION AND TO AVOID DELAY.

2) Use only foolscap size writing paper (but not of very thin variety) for writing your answers.
3) Leave 4 cm margin on the left, top and bottom of your answer sheet.
4) Your answers should be precise and in your own words.
5) Solve Part A and Part B of this assignment, and **submit the complete assignment answer sheets containing Parts A and B within the due date.**
6) The assignment answer sheets are to be submitted to your Study Centre as per the schedule. **Answer sheets received after the due date will not be accepted.**
   We strongly suggest that you retain a copy of your answer sheets.
7) This assignment is **valid from 1st January 2025 to 31st December 2025**. If you have failed in this assignment or fail to submit it by 31st December 2025, then you need to get the assignment for the year 2026, and submit it as per the instructions given in the Programme Guide.
8) **You cannot fill the examination form for this course** until you have submitted this assignment. For any queries, please contact: drsgupta@ignou.ac.in and slamba@ignou.ac.in. Please note that we do not provide answers to the questions in this Assignment. We wish you good luck.

Tutor Marked Assignment

NUCLEAR AND PARTICLE PHYSICS

Course Code: MPH-017
Assignment Code: MPH-017/TMA/2025
Max. Marks: 100

Note: Attempt all questions. The marks for each question are indicated against it.

PART A

1. a) A human body contains $0.245\,\text{kg}$ of normal potassium (K) of which 0.015 percent is the radioactive beta emitter potassium-40 $\left(\text{half}-\text{life} = 1.3\times10^{9}\ \text{yr}\right)$. Calculate the rate of production of $\beta-$particles in the body from the decay of potassium-40. What is the activity? (7)

   b) The mass defects for ^{235}U is $+49.899\,\text{MeV}$ and ^{27}Al is $-0.01847\,u$. Calculate the corresponding atomic mass. (5)

   c) Consider a square well potential

$$V(r)=\begin{cases}-V_0 & r\le r_0\\ 0 & r>r_0\end{cases}$$

   Obtain wavefunction of deuteron within the range of potential and outside.
   Given: Boundary energy of deuteron $(E_B)=2.225\,\text{MeV}$; $r_0=2.24\,\text{fm}$. (8)

   d) Explain tensor potential which justifies the non – zero quadrupole moment of deuteron. (5)

   e) Using the effective range formula, evaluate the total n-p scattering cross-section for a neutron interacting with a free proton in a laboratory at $10\,\text{MeV}$.

   Given: scattering lengths: $a_t=4.8\,\text{fm}$, $a_s=-21.3\,\text{fm}$,

   Effective range: $r_{ot}=1.6\,\text{fm}$, $r_{os}=2.24\,\text{fm}$. (5)

2. a) On the basis of semi-empirical mass formula, explain as why there are two mass parabola for even-A nuclei and only one for A-odd nuclei. (5)

   b) A nucleus $^{A}_{Z}X$ has energy levels at 0.025, 0.082, 0.160, 0.326 and $1.415\,\text{MeV}$. Which of these energies are expected to be the energy of members of the rotational band if the ground state of X is $\left(\frac{1}{2}\right)^{+}$. (5)

   c) i) Why do we need to cool the ^{60}Co sample in Wu's experiment? (2)

   ii) Prove that the law of conservation of angular momentum is not violated in β-decay if the intrinsic spin of neutrino is $\hbar/2$. (3)

   d) Using the nuclear shell model, obtain the magnetic moment and electric quadrupole moment of the ground state of $^{41}_{20}Ca$ and $^{41}_{21}Sc$ nuclei.

   Given : $(g_\ell)_p=1,\quad (g_s)_p=+5.58\,\mu_N$,

   $(g_\ell)_n=1,\quad (g_s)_n=-3.82\,\mu_N, r_0=1.2\,\text{fm}$ (5)

PART B

3. a) Tritium emits electrons and magnesium $\left(^{23}Mg\right)$ emits positrons. Represent the two decay processes by equations and calculate in each case the end-point energy of the particles emitted.

Given: $M\left(^{3}_{1}\mathrm{H}\right) = 3.01695\,u$; $M\left(^{0}_{\pm 1}\mathrm{e}\right) = 0.00055u$

$M\left(^{3}\mathrm{He}\ \right) = 3.01693\,u$; $M\left(^{23}\mathrm{Na}\right) = 22.99618\,u$ and $M\left(^{23}\mathrm{Mg}\ \right) = 23.0002\,u$. (5)

b) Write the Bethe-Weiszacker mass formula. Explain the various terms involved in it. Draw curves, between binding energy per nucleon versus mass number, which represents contribution of various terms in the semi-empirical mass formula of binding energy per nucleon. (5)

c) (i) The experimentally observed magnetic dipole moment of deuteron is $\mu_d = 0.8573\,\mu_N$. On the basis of observed dipole moment, what are the possible spin configurations in which neutron and proton can exist in deuteron. (2)

(ii) Justify the possible reasons for the deviation in the observed and expected value of magnetic dipole moment of deuteron. (3)

Given: $\mu_p = 2.7913\,\mu_N$. $\mu_n = 1.913\,\mu_N$.

d) A compound nucleus has a neutron resonance at 75 eV which is produced through a neutron entrance channel. The resonance state mainly decays through a neutron, gamma and alpha channel with the partial decay widths as $\Gamma_n = 4.4$ eV, $\Gamma_\gamma = 1.5$ eV and $\Gamma_\alpha = 2.9$ eV, respectively. Estimate the cross-section for (n, γ) and (n, α) reactions. (5)

4. a) List the quantum numbers associated with leptons. State whether they are conserved in strong, weak and electromagnetic interactions. Hence explain whether the following reactions are allowed:

i) $p \rightarrow e^{+} + \gamma$ ii) $\pi^{+} \rightarrow \mu^{+} + \nu_{\mu}$ (5)

b) Show that $\Sigma^{+} \rightarrow n + \pi^{+}$ is a weak interaction decay whereas $\Sigma^{0} \rightarrow \Lambda^{0} + \gamma$ is an electromagnetic decay. (5)

c) What are the four fundamental forces in nature? List the field particles that mediate these interactions and their properties. Which of the fundamental forces (interactions) are responsible for the neutrino flux from the sun and the neutrinos produced in the reactors? (5)

d) What is charge conjugation? Derive the eigenvalues of the charge conjugation operator. (5)

e) List the quantum numbers (B, J, I, I_3, s and Q) for the antiquarks $\bar{u}, \bar{d}, \bar{s}$. State the quark content for π^{+} and p. (10)

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