MPH-017

ASSIGNMENT BOOKLET

M.Sc. (Physics) Programme
(MSCPH)

NUCLEAR AND PARTICLE PHYSICS

Valid from 1st January, 2026 to 31st December, 2026

School of Sciences
Indira Gandhi National Open University
Maidan Garhi, New Delhi-110068
(2026)

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 2026 to 31st December 2026**. If you have failed in this assignment or fail to submit it by 31st December 2026, then you need to get the assignment for the year 2027, 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/2026
Max. Marks: 100

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

PART A

1. a) Calculate the mass defect of Boron-10 and proton separation energy.
Given:

$M\left(^{10}\text{B}\right) = 10.0129369\ \text{u}$

$M\left(^{9}\text{Be}\right) = 9.0121831\ \text{u}$

$M(\text{Proton}) = 1.0078250\ \text{u}$ (5)

b) The mass defects for ^{7}Li and ^{240}Pu are 0.040 u, and 1.9324 u respectively. Calculate the corresponding atomic mass. (5)

c) For the nuclear charge density $\rho_{ch} = \rho_0 e^{-q_0 r}$, compute the charge form factor and the mean square charge radius $\left\langle r^2 \right\rangle$. (5)

d) Explain and justify the observed deviations in magnetic dipole moment and quadrupole moment of deuteron. (5)

e) i) List any three major differences between low energy *n-p* scattering and *p-p* scattering. (3)

ii) Calculate the third component of isospin T_3 for $^{35}_{17}\text{Cl}$ and $^{32}_{16}\text{S}$. (2)

2. a) Write the semi-empirical mass formula. On the basis of semi-empirical mass formula, derive the condition of stability of a given nucleus. (5)

b) Determine the expected shell-model quadrupole moment of $^{209}\text{Bi}(9/2)$. (5)

c) i) Write short notes on

- Internal conversion,
- Nuclear isomerism
- β-decay process with one example. (5)

d) Obtain an expression of momentum distribution of β-particles in the momentum range p_β to $\left(p_\beta + dp_\beta\right)$, considering the Coulomb correction term. Also, derive the energy distribution function to get the shape of the β-decay spectrum. (5)

e) Calculate the energy produced (in Joules) by fission of 10 g of ^{235}U.
Given: The energy released per fission of ^{235}U is 200 MeV. (5)

PART B

3. a) What is reciprocity theorem of nuclear reactions? Obtain its mathematical expression. Rewrite the reciprocity theorem considering the spin of all the involved nuclei. (2+1+2)

   b) A reactor operating at a power level of 1000 MW uses thermal neutrons producing fissions of ^{235}U. If the thermal flux is $10^{16} m^{-2} s^{-1}$, calculate the mass of ^{235}U present in the reactor? Assume $\sigma_f = 580$ b. (5)

   c) Explain the phenomenon of nuclear fission. What is the importance of chain reactor in nuclear fission? Explain briefly the principle of operation of a nuclear reactor. (2+1+2)

   d) A thin $^{7}_{3}Li$ target of 0.01 mm thickness is bombarded with a proton beam resulting in 10^{9} neutron/s. Calculate the reaction cross-section σ for this nuclear reaction.

   Given: Density of $^{7}_{3}Li = 500\ kg\ m^{-3}$. (5)

   e) Define *Q*-value of a nuclear reaction. Calculate the *Q*-value of the reaction: $^{14}N(\alpha, p)\ ^{17}O$. Given:

   $M\left(^{14}N\right) = 14.00753$ u

   $M\left(^{4}He\right) = 4.00386$ u

   $M\left(^{1}H\right) = 1.00813$ u

   $M\left(^{17}O\right) = 17.0045$ u

   Whether the reaction is exoergic or endoergic? (5)

4. a) Check if isospin is conserved in the following reactions:

   i) $\pi^{+} + n \rightarrow \pi^{0} + p^{+}$

   ii) $K^{-} + p^{+} \rightarrow \pi^{0} + \Lambda^{0}$ (6)

   b) Explain why we must define an intrinsic parity for each particle. (4)

   c) From the isospin and hypercharge assignment show that the *t* and *b* quarks have charges $+2/3$ and $-1/3$ respectively. (5)

   d) Write down the wave function for $\left|\pi^{-}\right\rangle$. Use the isospin raising operator to derive the wavefunctions for $\left|\pi^{0}\right\rangle$ and $\left|\pi^{+}\right\rangle$. (5)

   e) Consider *K* meson of mass m_K decaying into two pions of mass m_π each, in the laboratory frame. Show that the energy of each pion is equal to $\frac{m_K}{2}$ and the momenta are $p_\pi = \frac{1}{2}\sqrt{m_K{}^2 - 4m_\pi{}^2}$. (5)

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