

MPH-004

ASSIGNMENT BOOKLET

**M.Sc. (Physics) Programme
(MSCPH)**

QUANTUM MECHANICS-I

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). 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. The total marks for this assignment is 100, of which 40 marks are needed to pass it.

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:

ENROLMENT NO.:

NAME:

ADDRESS:

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.
- 5) **Submit the complete assignment answer sheets containing Part A and Part 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 shall 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 December 31, 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: mbnewmai@ignou.ac.in, slamba@ignou.ac.in

We wish you good luck.

Tutor Marked Assignment QUANTUM MECHANICS-I

Course Code: MPH-004
Assignment Code: MPH-004/TMA/2026
Max. Marks: 100

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

PART A

- Electrons are accelerated through a potential 150 V and incident on a crystal with interatomic spacing $d = 0.20$ nm. Calculate the de Broglie wavelength and the first-order Bragg diffraction angle. (5)
 - Estimate the uncertainty in the energy of a photon localized within a distance of 0.1 nm. (5)
 - i) Normalize the wave function:

$$\psi(x,0) = N \left[\sin\left(\frac{\pi x}{L}\right) + \sin\left(\frac{2\pi x}{L}\right) \right], \quad 0 \leq x < L.$$

- ii) Calculate the expectation value of x for a particle in this state. (5+5)

- d) A quantum mechanical particle in one dimension has the wave function:

$$\psi(x) = Nx^n : x > 0 ; n > 1.$$

Use the Schrödinger equation to determine the corresponding potential $V(x)$. (5)

- A 1.5 mA beam of electrons enters a sharply defined boundary with a velocity 3.0×10^6 ms⁻¹, and then its velocity reduces to 2.0×10^6 ms⁻¹, due to the difference in potential. Calculate the transmitted and reflected currents. (5)
 - Show that for any stationary state of a symmetric potential well: $\langle x^2 \rangle \neq 0$. (5)
 - Calculate the expectation value of the potential energy for the first excited state of a simple harmonic oscillator. (5)
 - Write down the eigenfunctions for the ψ_{300} and ψ_{310} states of the hydrogen atom.
 - Write the eigenvalues of \hat{L}^2 and \hat{L}_z for the states ψ_{300} and ψ_{310} .
 - Calculate the most probable value of r for the hydrogen atom in the state ψ_{210} . (2+2+6)

PART B

- Consider the following state vectors: $|\psi\rangle = \begin{pmatrix} 1 \\ i \\ -1 \end{pmatrix}$; $|\phi\rangle = \begin{pmatrix} 2 \\ 1-i \\ i \end{pmatrix}$. Calculate (i) the norm of $|\psi\rangle$ and (ii) the inner product $\langle \psi | \phi \rangle$. (3+3)

b) If an operator \hat{O} is Hermitian and an operator \hat{U} is unitary, show that the operator $\hat{U}\hat{O}\hat{U}^{-1}$ is Hermitian. (4)

c) The spectral representation of an operator $\hat{\Omega}$ in a two-dimensional orthonormal basis $|\phi_1\rangle, |\phi_2\rangle$ is

$$\hat{\Omega} = 3|\phi_1\rangle\langle\phi_1| + \sqrt{2}|\phi_1\rangle\langle\phi_2| + \sqrt{2}|\phi_2\rangle\langle\phi_1| + 2|\phi_2\rangle\langle\phi_2|$$

Determine the matrix elements of $\hat{\Omega}$. (5)

d) $|1\rangle$ and $|2\rangle$ are the orthonormal basis states of a two-dimensional Hilbert space. A Hermitian operator \hat{A} in this basis is given by the spectral representation: $\hat{A} = 3|1\rangle\langle 1| - |2\rangle\langle 2|$. For a normalized state given by

$$|\psi\rangle = \frac{1}{2}|1\rangle + \frac{\sqrt{3}}{2}|2\rangle, \text{ calculate } \langle\hat{A}\rangle \text{ and the root mean square deviation in } \hat{A}. \quad (5)$$

e) Derive the Heisenberg equations of motion for \hat{S}_x and \hat{S}_y for the Hamiltonian $\hat{H} = \omega\hat{S}_z$. (5)

4. a) For the simple harmonic oscillator

i) Show that $[\hat{H}, \hat{a}] = -\hbar\omega\hat{a}$.

ii) Calculate the matrix element $\langle n|\hat{x}|n+1\rangle$ (5+5)

b) i) Write down the angular momentum states $|j, m_j\rangle$ and calculate the matrix elements of \hat{J}_x, \hat{J}_y and \hat{J}_z for $j = 1/2$.

ii) For the angular momentum state $|3, 1\rangle$ show that $J_+|3, 1\rangle = \hbar\sqrt{10}|3, 2\rangle$ and $J_-|3, 1\rangle = 2\hbar\sqrt{3}|3, 0\rangle$. (6+4)

c) Show that in the terms of the $|\uparrow\rangle$ and $|\downarrow\rangle$ basis vectors defined by

$$\hat{S}_z|\uparrow\rangle = \frac{\hbar}{2}|\uparrow\rangle; \hat{S}_z|\downarrow\rangle = -\frac{\hbar}{2}|\downarrow\rangle, \text{ we can write: } \hat{S}_x = \frac{\hbar}{2} [|\uparrow\rangle\langle\downarrow| + |\downarrow\rangle\langle\uparrow|] \quad (5)$$
