MPH-008

ASSIGNMENT BOOKLET

M.Sc. (Physics) Programme
(MSCPH)

QUANTUM MECHANICS-II

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). 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, 2025 to 31st December, 2025**. If you have failed in this assignment or fail to submit it till its validity, then you need to get the assignment for the next year and submit it as per the instructions given in the Programme Guide.
8) For any queries, please contact: mbnewmai@ignou.ac.in, slamba@ignou.ac.in

We wish you good luck.

Tutor Marked Assignment
QUANTUM MECHANICS-II

Course Code: MPH-008
Assignment Code: MPH-008/TMA/2025
Max. Marks: 100

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

PART A

1. a) Write the space translation operator in quantum mechanics $\hat{T}(\vec{a})$ for an infinitesimal translation $\vec{a}$. Hence evaluate the commutators: $\left[\hat{x}, \hat{T}(\vec{a})\right]$ and $\left[\hat{p}_x, \hat{T}(\vec{a})\right]$ (5)

   b) Show that for a Hamiltonian $\hat{H} = \dfrac{\hat{p}_x{}^2}{2m} + V(x)$ to commute with the time reversal operator $\hat{\Theta}$ the potential function $V(x)$ must be real. (5)

2. a) Construct the wave function $\psi(x_1, x_2, x_3)$ for a system of 3 identical fermions in the states $\left|\psi_1\right\rangle, \left|\psi_2\right\rangle, \left|\psi_4\right\rangle$ respectively of an one-dimensional box of size *A.* (5)

   b) Calculate the ground state energy for a system of five identical spin - $\dfrac{1}{2}$ particles placed in a one-dimensional simple harmonic oscillator potential of frequency ω_0. (5)

3. For a system of two particles each with angular momentum one $\left(j_1 = j_2 = 1\right)$.

   (i) Construct the normalized states of highest and second highest J_z for total angular momentum 2.

   (ii) Construct the normalized state of highest J_z for total angular momentum 1. (10)

4. Consider the following symmetric two-dimensional infinite potential well

$$V(x,y) = \begin{cases} 0 & \text{for } 0 \le x \le L,\ 0 \le y \le L \\ \infty & \text{otherwise} \end{cases}$$

   Determine the first order perturbation correction to the energy eigenvalue of the two-fold degenerate first excited state, for the following perturbation: $H_1(x,y) = xy$. (10)

5. Determine the upper bound to the ground state energy for a particle in a one-dimensional box of length L, using the trial wave function: $\psi(x) = x(L - x)$. (10)

PART B

6. Consider the motion of a quantum particle in a potential $V(x) = \alpha x^6$. Use the WKB approximation to determine how the energy of the bound state E_n varies with n and α for large values of n. (10)

7. A particle is in the ground state of the simple harmonic oscillator of frequency ω. At $t = 0$ frequency of the oscillator changes from ω to $\omega_1 = 3\omega$. Calculate the probability for the particle to remain in the ground state at $t > 0$. (10)

8. For a static (time-independent) perturbation V suddenly switched on at time $t = 0$:

$$V = \begin{cases} 0 & t < 0 \\ V & t > 0 \end{cases}$$

show that the transition probability for a transition of the system from a state $|i\rangle$ to a state $|n\rangle$ up to first order in perturbation theory is just: $P_{i\to n} = \dfrac{4|V_{ni}|^2}{\omega_{ni}^2 \hbar^2}\sin^2\left(\dfrac{\omega_{ni} t}{2}\right)$. How does the transition probability change if the time of application is doubled in the limit $t \to 0$. (6+4)

9. For a Dirac particle moving in a central potential, show that the orbital angular momentum is not a constant of motion. (10)

10. Consider the scattering of a particle of mass m by the following potential

$$V(r) = \begin{cases} -U_0, & 0 < r < R_0 \\ 0, & r > R_0 \end{cases}$$

Assuming that the scattering is mainly due to s-waves ($l = 0$), calculate the s-wave phase shift. (10)

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