MPH-008

ASSIGNMENT BOOKLET

M.Sc. (Physics) Programme
(MSCPH)

QUANTUM MECHANICS-II

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 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/2026
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 $\hat{T}(a)$ for a finite translation a along the x direction. Calculate the commutator $\left[\hat{x}, \hat{T}(a)\right]$. You may use the Baker-Campbell-Hausdorff formula: $e^{\hat{A}}\,\hat{B}\,e^{-\hat{A}} = \hat{B} + \left[\hat{A}, \hat{B}\right] + \frac{1}{2}\left[\hat{A}, [\hat{A}, \hat{B}]\right] + \ldots$. (5)

   b) Consider an operator $\hat{O}$ for which $\hat{\boldsymbol{\pi}}^{\dagger}\,\hat{O}\,\hat{\boldsymbol{\pi}} = -\hat{O}$. Show that the expectation value of $\hat{O}$ in a parity eigenstate is zero. (5)

2. a) Determine the wave function and energy of the ground state and first excited state for a system of two identical bosons in 1D simple harmonic oscillator. (5)

   b) Define the action of the permutation operator $\hat{P}_{12}$ for a system of two particles 1 and 2 and two states $|\psi_P\rangle$ and $|\psi_{P'}\rangle$. Show that $\hat{P}_{12}{}^2 = \hat{\mathbf{I}}$ and determine the eigenvalues of $\hat{P}_{12}$. (5)

3. a) Write down the eigenkets $|j, m_j\rangle$ for $j = j_1 + j_2$ with $j_1 = 2; j_2 = \frac{1}{2}$.

   b) Calculate the matrix elements for J^2 for a system of two spin half particles. (5+5)

4. Determine the first and second order perturbation correction to the ground state energy eigenvalue of the one-dimensional infinite potential well of width L ($0 \le x \le L$) with the perturbation: $H_1(x) = V_0 \sin\left(\frac{\pi x}{L}\right)$. (10)

5. Consider the following one-dimension simple harmonic oscillator Hamiltonian operator

$$\hat{H} = -\frac{\hbar^2}{2m}\frac{d^2}{dx^2} + \frac{1}{2}m\omega^2 x^2$$

   Use a trial wave function $\psi(x) = N\exp(-\frac{x^2}{2\alpha^2})$ with a variational parameter α to estimate the upper bound to the ground state energy. (10)

PART B

6. Determine the WKB approximation for the bound state energy of a particle of mass m in the potential:

$$V(x)=\begin{cases} a|x| & x\geq 0 \\ 2a|x| & x<0 \end{cases}$$ (10)

7. Consider the two state problem in which the unperturbed Hamiltonian $\hat{H}_0$ has just two eigenkets, $|1\rangle$ and $|2\rangle$ with: $\hat{H}_0|1\rangle = E_1|1\rangle; \hat{H}_0|2\rangle = E_2|2\rangle$, and $E_2 > E_1$. The system is subjected to a time-dependent perturbation: $\hat{V}(t) = V_0\cos(\omega t)\big[|1\rangle\langle 2| + |2\rangle\langle 1|\big]$.

   Calculate the probability for the system to be in the state $|2\rangle$ at time *t,* given that it is in the state $|1\rangle$ at $t=0$. (10)

8. A charged particle of mass m and charge q, is confined to a one-dimensional box of side *L* with $0\leq x\leq L$. At $t>0$, an electric field $\vec{E}=E_0 e^{-\alpha t}\hat{i}$ acts on the particle where α is a constant. If the particle is in the ground state when $t<0$, calculate the probability that it will be in the first excited state for $t>0$. (10)

9. Using the Born Approximation, calculate the differential cross-section for a beam of particles of mass *m* scattered by a potential: $V(r)=V_0\frac{a}{r}\exp\left(-\frac{r}{a}\right)$. You may use:

   $$\int_0^\infty e^{-\alpha x}\sin(\beta x)dx=\frac{\beta}{\alpha^2+\beta^2} \quad \text{for} \quad \alpha>0$$ (10)

10. a) Explain how the expression for the energy levels obtained by solving Klein Gordon equation for a Coulomb field differs from the results derived from Schrödinger equation. Why is this solution not able to explain the fine-structure splitting of the energy levels?

    b) Derive the current conservation equation from the Dirac equation. (5+5)

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