

QP CODE: 26801768



Reg No :

Name :

INTEGRATED M.Sc. DEGREE EXAMINATION, APRIL 2026

Eight Semester

INTEGRATED M.Sc. BASIC SCIENCES-PHYSICS

CORE - IPH8CR02 - QUANTUM MECHANICS-II

2021 Admission Onwards

AC9F6E68

Time: 3 Hours

Weightage: 30

Part A (Short Answer Questions)

*Answer any **eight** questions.*

Weight 1 each.

1. Explain the difference between orthogonal and orthonormal sets of vectors. Can a set be orthogonal but not orthonormal? Justify with an example in $\mathbb{R}^2$?
2. Let $\mathbb{W} = \{(x, y) : x + y = 0, x, y \in \mathbb{R}\}$. Show that $\mathbb{W}$ is a subspace of $\mathbb{R}^2$.
3. (a) Express the singlet state in the product basis.
(b) What are the S^2 and S_z eigenvalues for the singlet state?
(c) Is the singlet state symmetric or anti-symmetric under exchange of particles?
4. Under a rotation transformation represented by a unitary operator $U(R)$, how do scalar quantities, vector operators, and rank-2 tensor operators transform in quantum mechanics? Provide the mathematical form of each transformation; no need to take the small-angle limit.
5. Calculate $[a^\dagger, a]$, where a and $a^\dagger$ are raising and lowering operators of one one-dimensional harmonic oscillator.
6. Let A be a hermitian operator that commutes with H^0 and H' . If ψ_a^0 and ψ_a^0 are also eigen functions of A , with distinct eigenvalues, then prove that in the W-matrix $W_{ab} = 0$.
7. What are the advantages and drawbacks of the Rayleigh-Ritz variational method?
8. After how much time do you have to turn off the perturbation (if it is sudden) to catch the system in the upper state? Explain your reason with a figure.
9. What is the scattering amplitude? How is it related to the scattering cross-section?
10. Write a short note on the scattering due to the Coulomb potential.

(8×1=8 weightage)





Part B (Short Essay/Problems)

Answer any **six** questions.

Weight 2 each.

11. Let $\Omega : \mathbb{R}^2 \rightarrow \mathbb{R}^2$ be a linear operator, defined as

$$\begin{aligned}\Omega|1\rangle &= 2i|1\rangle + 3|2\rangle, \\ \Omega|2\rangle &= -3|1\rangle + 6i|2\rangle,\end{aligned}$$

in the standard orthonormal basis $\{|1\rangle, |2\rangle\}$.

(a) Write the expression of $\langle 1|\Omega^\dagger, \langle 2|\Omega^\dagger$.

(b) Write Ω and $\Omega^\dagger$ in the Dirac notation.

(c) Let $|v\rangle = |1\rangle + |2\rangle$ and $|w\rangle = 2|2\rangle$, show that $\langle v|\Omega^\dagger|w\rangle = \langle v|\Omega w\rangle$.

12. Let $\Omega : \mathbb{R}^2 \rightarrow \mathbb{R}^2$ be a linear operator, defined as

$$\Omega = \begin{bmatrix} 5 & 9 \\ 6 & -3 \end{bmatrix}.$$

Find the matrix representation of Ω in the basis

$$\left\{ \begin{bmatrix} 1 \\ 1 \end{bmatrix}, \begin{bmatrix} -1 \\ 1 \end{bmatrix} \right\}.$$

13. Using the definition of angular momentum $L_i = (\vec{X} \times \vec{P})_i$ and commutator relations of X_i , and P_i ,

(a) Show that $[L_x, L_y] = i\hbar L_z$.

(b) Show that $[L^2, L_z] = 0$, use $[L_i, L_j] = 0$.

(c) Why should there exist a common eigenvector basis for L^2 and L_z ?

14. Using time-independent perturbation theory, discuss the anharmonic oscillator problem.
15. Calculate the first-order correction in the n th state of the wave function for the charged harmonic oscillator.
16. Discuss the classical region of the potential ($E > V$) where the particle is confined, using the WKB method.
17. Compare Schrodinger, Heisenberg and Dirac pictures in Quantum Mechanics.
18. Discuss quantum hard sphere scattering.

(6×2=12 weightage)

Part C (Essay Type Questions)

Answer any **two** questions.

Weight 5 each.

19. Discuss how power series and the limit definition of derivatives are used to define functions of linear operators. Define the following operators using power series: $\sqrt{\Omega}$, $\sin \Omega$, $e^{i\Omega}$. Given an orthonormal eigenbasis for Ω , $\Omega = \sum_{i=1}^n \omega_i |\omega_i\rangle$, derive the matrix representation of e^{Ω} in this basis.
20. Using degenerate perturbation theory, discuss the Stark effect in the hydrogen atom.





21. Using the variational principle/method, estimate the ground state energy of the following cases

1. A particle subject to the linear potential $V(x) = mgx$ but with an infinite potential barrier at $x = 0$.
2. A particle subject to the quartic potential.

22. State and prove Ehrenfest's theorem.

(2×5=10 weightage)

