(6 pages) **Reg. No. :** .....

**Code No. : 8841** **Sub. Code : KPHM 31**

M.Sc. (CBCS) DEGREE EXAMINATION, NOVEMBER 2017.

Third Semester

Physics

QUANTUM MECHANICS — I

(For those who joined in July 2016 and afterwards)

Time : Three hours Maximum : 75 marks

PART A — (10 × 1 = 10 marks)

Answer ALL questions.

Choose the correct answer:

1. The relation between phase velocity ($u$) and group velocity ($v$) for a non-relativistic free particle is

(a) $u = v$ (b) $u = \frac{1}{2}k$

(c) $u = \frac{1}{3}v$ (d) $u = 2v$

2. For a free particle, the potential energy V is

(a) less than 1 (b) greater than 1

(c) zero (d) infinite

3. The eigen values of a Hermitian operator are all

(a) imaginary

(b) real

(c) both imaginary and real

(d) none

4. The asymphotic wave function of linear harmonic oscillator is

(a) $u(\varepsilon) = \varepsilon^n e^{\varepsilon^2}$ (b) $u(\varepsilon) = \varepsilon^n e^{\pm \frac{1}{2}\varepsilon^2}$

(c) $u(\varepsilon) = e^{\frac{1}{2}\varepsilon^2}$ (d) $u(\varepsilon) = e^{\frac{1}{4}\varepsilon^2}$

5. In which picture, the operators and the state vectors both change in time

(a) Schroedinger (b) Interaction

(c) Heisenberg (d) None

6. The density matrix was developed by

(a) Van Neumann (b) Schroedinger

(c) Planck (d) Heisenberg

7. The rotational energy values of the rigid rotator is

(a) $E = \frac{m^2\hbar^2}{2I}$ (b) $E = \frac{(2m+1)\hbar^2}{2I}$

(c) $E = \frac{m^3\hbar^2}{3I}$ (d) none

8. The probability of finding the particle outside the classical limits in the normal state of the harmonic oscillator is

(a) 16% (b) 84%
(c) 50% (d) 100%

9. Which of the following is true?

(a) $\left[\hat{J}^2, \hat{J}\right] = i\hbar$ (b) $\left[\hat{J}^2, \hat{J}\right] = 2i\hbar$
(c) $\left[\hat{J}^2, \hat{J}\right] = 0$ (d) none

10. Clebsch-Gordon coefficients are related with
(a) degenerate states
(b) non-degenerate states
(c) spin states
(d) angular momentum states

PART B — ($5 \times 5 = 25$ marks)

Answer ALL questions, choosing either (a) or (b).

Each answer should not exceed 250 words.

11. (a) How does the concept of Bohr's orbit relate the uncertainty relation? Explain.

Or

(b) What is the physical interpretation of the wave function? What are the normalized and orthogonal wave function.



12. (a) What is Hilbert space? Explain the representation of state vectors in Hilbert space.

Or

(b) Prove that the parity operator is Hermitian and unitary.

13. (a) Outline the Poisson brackets and commutator bracket.

Or

(b) Construct the density matrix for an ensemble.

14. (a) What are the radial part of Schroedinger's equation for hydrogen atom and solve it to obtain the energy levels for the electron.

Or

(b) Determine the energy levels of a linear harmonic oscillator on the basis of the Schroedinger's equation.

15. (a) Construct the matrix representation of $J^2$ and $J_x$ for $j = \frac{1}{2}$.

Or

(b) Prove that rotation in space leads to conservation of angular momentum.

PART C — (5 × 8 = 40 marks)

Answer ALL questions, choosing either (a) or (b).

Each answer should not exceed 600 words.

16. (a) Derive the time independent Schroedinger equation and hence discuss its solutions and also the probability current density.

Or

(b) Show that the Gaussian wave packet is a limiting case of position and momentum uncertainity.

17. (a) Prove that (i) Hermitian operators have real eigen values and (ii) two eigen functions of a Hermitian operator are orthogonal to each other if the corresponding eigen values are unequal.

Or

(b) Develop the matrix theory of harmonic oscillator and obtain matrices for $a, p$ and $H$.

18. (a) Compare the Schrodinger, Heisenberg and interaction pictures.

Or

(b) Construct the density matrix for a spin $\frac{1}{2}$ particle.



19. (a) What do you mean by tunnelling through a barrier? A particle travelling with energy E along X-axis has a potential barrier defined as

$$v(x) = \begin{cases} 0 & \text{for} \quad x < 0 \\ V_0 & \text{for} \quad 0 < x < a \\ 0 & \text{for} \quad x > a \end{cases}$$

Determine the expressions for the reflection and transmission co-efficient of the particle.

Or

(b) Give the theory of a three dimensional square well potential and hence find the solutions in exterior and interior regions

20. (a) Obtain the matrix of Clebsch-Gordan coefficients for $j_1 = 1$ and $j_2 = 1$.

Or

(b) Evaluate $\left[L_x, L_y\right]$ Show that $L^2$. Commutes with $L_x$.

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