M. Sc. PHYSICS

FIRST SEMESTER

QUANTUM MECHANICS-I

(MPH-103)

Duration: 3 Hrs. **Marks: 70**

{ PART : A (OBJECTIVE) = 20
PART : B (DESCRIPTIVE) = 50 }

[PART B – Descriptive]

Duration: 2 Hrs. 40 Mins. **Marks: 50**

[Answer question no. One (1) & any four (4) from the rest]

1. **(a).** What do you mean by wave particle duality? Explain with examples in support of it. 2+3=5

   (b). **(i)** Show that the wavelength of the quantum wave associated with the electron accelerated through a potential difference of 150 volts lie in X-ray range. 3+2=5

   (ii) Calculate the momentum gained by an electron when it is accelerated through a potential difference of 100 volts.

2. State Heisenberg's uncertainty principle. Describe an experiment to establish the principle. An electron has a speed of 500 m/s with an accuracy of 0.004%. Calculate the uncertainty with which you can locate the position of the electron. 2+5+3 =10

3. Discuss Louis de Broglie's argument for the matter wave. How Schrödinger established the validity of matter wave. Describe the Davisson- Germen experiment to indicate the correctness of the de Broglie hypothesis. 2+3+5 =10

4. **(a)** What do you mean by Hermitan operator? 4+4+2 =10
   If A is a Hermitan operator & ψ is its eigen function show that $< A^2 >= \int |A\psi|^2 \, d\tau$

   (b) Show that the operator $i\frac{d}{dx}$ and $\frac{d^2}{dx^2}$ are hermitian.

   (c) Prove that the eigen values of hermitian operator are real.

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5. Explain the meaning of identical particles. Distinguish between classical and quantum identical particles. Define particle exchange operator and calculate the eigen values of the particle exchange operator. 2+(2+2)+1+3 =10

6. (a) Show that (i). $[\ \widehat{L^2}\ ,\ \widehat{Lx}\ ] = 0$ (2+3)+5 =10

   (ii). $[\ \widehat{Lx}\ ,\ \widehat{Ly}\ ] = i\hbar\,\widehat{Lz}$

   (b) Calculate the Eigen values and Eigen functions of $\widehat{L^2}$ and $\widehat{Lz}$.

7. What do you mean by symmetric and Antisymmetric wave functions? Construct the symmetric wave function from unsymmetric wave functions. Explain exchange energy. Discuss how spin statistics are connected with symmetric and antisymmetric wave functions. (2+2)+3+1+2 =10

8. (a). Using ground state wave function of the harmonic oscillator, calculate (i) average potential energy and (ii) average kinetic energy of the oscillator. 3+3=6

   (b). Deduce the expression for radial probability density in case of H-atom. Calculate the position of maximum probability density P_{10} for the ground state of H-atom. 2+2=4

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Duration: 20 Mtns. **Marks: 20**

[PART : A – Objective]

Marks

A. Tick (☑) the Correct Answer from the following: **1x20= 20**

1. Which of the following is acceptable wave function?

☐ **a.** $\psi = e^x$ ☐ **b.** $\psi = x$ ☐ **c.** $\psi = \tan x$ ☐ **d.** $\psi = \sin x$

2. Two function are orthogonal if their inner product

☐ **a.** 1 ☐ **b.** -1 ☐ **c.** $\frac{\hbar}{2}$ ☐ **d.** 0 (Zero)

3. Which of the following is not a Physical requirement for an acceptable wave function?

☐ **a.** Single valued ☐ **b.** Continuous in the given region ☐ **c.** Square integrable ☐ **d.** Symmetric

4. The commutation relation between position and momentum operator is

☐ **a.** $[q_j , p_k] = 0$ ☐ **b.** $[q_j , p_k] = 1$ ☐ **c.** $[q_j , p_k] = -i\hbar\, \delta jk$ ☐ **d.** $[q_j , p_k] = i\hbar\, \delta jk$

5. The kinetic energy operator in one dimension is

☐ **a.** $-i\hbar \frac{\partial}{\partial x}$ ☐ **b.** $i\hbar \frac{\partial}{\partial x}$ ☐ **c.** $-i\hbar \frac{\partial}{\partial t}$ ☐ **d.** $-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}$

6. The eigen value of $\hat{P}_{21}$ is

☐ **a.** +1 ☐ **b.** 0 ☐ **c.** ±1 ☐ **d.** - 1

7. The $\widehat{P_y}$ operator is defined as $-i\hbar \frac{\partial}{\partial y}$. Then $\widehat{P_y^3}$ is given by

☐ **a.** $-i\hbar^3 \frac{\partial^3}{\partial y^3}$ ☐ **b.** $-i\hbar \frac{\partial^3}{\partial y^3}$ ☐ **c.** $i\hbar^3 \frac{\partial^3}{\partial y^3}$ ☐ **d.** $i\hbar \frac{\partial^3}{\partial y^3}$

8. The exchange energy between two electrons is related when they have

☐ **a.** Same spin ☐ **b.** Opposite spin ☐ **c.** Same spin in degenerate orbital ☐ **d.** Opposite spin in non-degenerate orbital

Contd…..

Marks

9. The energy required to excite to the first excited state of a particle of mass 'm' confined in a length 'l' is

- [ ] a. $\frac{h^2}{8ml^2}$
- [ ] b. $\frac{\hbar^2}{8ml^2}$
- [ ] c. $\frac{3h^2}{8ml^2}$
- [ ] d. $\frac{3\hbar^2}{8ml}$

10. Conjugate of the operator $\hat{A} = \hbar\frac{d}{dx}$ is $\hbar\frac{d}{dx}$. Then conjugate of the operator $\hat{O} = i\hbar\frac{d}{dx}$ is

- [ ] a. $i\hbar\frac{d}{dx}$
- [ ] b. $i^2\hbar\frac{d}{dx}$
- [ ] c. $-i\hbar\frac{d}{dx}$
- [ ] d. $\frac{d}{dx}$

11. Energy of a particle in a 3-D box is $\frac{7h^3}{4ma^2}$. The degree of degeneracy is

- [ ] a. 3
- [ ] b. 6
- [ ] c. 4
- [ ] d. 1

12. An orbital is a/an

- [ ] a. Circular path
- [ ] b. One electron wave function
- [ ] c. Operator
- [ ] d. Observable property

13. The ratio of number nodes in the second excited state and the ground state of a particle in a 1-D box is

- [ ] a. 2
- [ ] b. $\propto$
- [ ] c. 1
- [ ] d. 3

14. The number of nodes in a radial function of H like atom is

- [ ] a. *n-l-2*
- [ ] b. *n-l-1*
- [ ] c. *n-l*
- [ ] d. *n+l-1*

15. If r_n denotes the approximate value of r which gives us the maximum value of Radial distribution function, it is given by

- [ ] a. $r_n = \frac{n^2}{a_0}$
- [ ] b. $r_n = n^2 a_0$
- [ ] c. $r_n = n a_0$
- [ ] d. $r_n = n/a_0^2$

16. For the ground state of the particle in one dimensional box of length 'a' the quality $\langle x \rangle . \langle Px \rangle$ is equal to

- [ ] a. 0
- [ ] b. 1
- [ ] c. a/2
- [ ] d. 2a

17. Which of the following obey Fermi-Dirac Statistics?

- [ ] a. Muon (μ^-)
- [ ] b. Pion (π^+)
- [ ] c. Kaon (K^+)
- [ ] d. η meson

P.T.O.

Marks

18. The commutator $[\widehat{Ly}, \widehat{Lx}]$ has a value equal to

☐ **a.** $-i\hbar\widehat{Lz}$ ☐ **b.** 0 ☐ **c.** $-i\widehat{Lz}$ ☐ **d.** $\hbar\widehat{L_z}$

19. If ψ is wave function, the probability of finding an electron in a given orbital is proportional to

☐ **a.** ψ^2 ☐ **b.** $\sqrt{\psi}$ ☐ **c.** ψ^3 ☐ **d.** $\psi/2$

20. 2s orbital of Hydrogen atom has a radial node at $2a_0$ because ψ_{2s} orbital is proportional to

☐ **a.** $(2 - {}^{r}/_{a_0})$ ☐ **b.** $(2 + {}^{r}/_{a_0})$ ☐ **c.** $\left(2 - \frac{r}{2a_0}\right)$ ☐ **d.** $\left(1 + \frac{r}{2a_0}\right)$