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E–511

M. Sc. (Second Semester) (ATKT) EXAMINATION, May-June, 2021

PHYSICS

Paper First

(Quantum Mechanics—I)

Time : Three Hours] [*Maximum Marks : 80*

Note : Attempt all Sections as directed.

Section—A 1 each

(Objective/Multiple Choice Questions)

Note : Attempt all questions.

Choose the correct answer :

1. In stationary states which of the following is not true ?
   (a) position probability density remains independent of time.
   (b) energy does not have a perfect definite value.
   (c) expectation value of all dynamical variable are independent of time.
   (d) energy has a perfect definite value.

2. The expectation value of momentum P is :
   (a) $\int \psi^* \psi \left(\frac{\hbar}{i} \nabla \right) d\tau$
   (b) $\int \frac{\hbar}{i} \nabla \left(\psi^* \psi \right) d\tau$
   (c) $\int \psi^* \left(\frac{\hbar}{i} \nabla \right) \psi d\tau$
   (d) None of the above
3. Schrödinger gave the physical significance of wave function ψ in terms of :
   (a) charge density
   (b) probability density
   (c) auxiliary mathematical quantity
   (d) None of the above
4. Electrastatic force between two electric charges are :
   (a) conservative force
   (b) non-conservative force
   (c) frictional force
   (d) None of the above
5. Commutator of two non-commuting Hermitian operator is :
   (a) Hermitian
   (b) Anti-Hermitian
   (c) Either Hermitian or Anti-Hermitian
   (d) None of the above

6. Which of the following equation is a representation of Dirac delta function $\delta(x)$?

(a) $\delta(x) = \lim_{L\to\infty}\left(\frac{\sin^2 \lfloor x}{\pi x^2}\right)$

(b) $\delta(x) = \lim_{L\to\infty}\left(\frac{\cos \lfloor x}{\pi x}\right)$

(c) $\delta(x) = \lim_{L\to\infty}\left(\frac{\sin \lfloor x}{\pi x}\right)$

(d) $\delta(x) = \lim_{L\to\infty}\left(\frac{\cos^2 \lfloor x}{\pi x}\right)$

7. If bra is put on left of ket it forms :

(a) linear operator

(b) non-linear operator

(c) scalar product

(d) None of the above

8. Energy raising and lowering operator satisfy the following relation :

(a) $aa^+ = \frac{H}{\hbar\omega_c} + \frac{1}{2}$

(b) $a^+a = \frac{H}{\hbar\omega_c} + \frac{1}{2}$

(c) $aa^+ = \frac{H}{\hbar\omega_c} - \frac{1}{2}$

(d) None of the above

9. A system is known to be in a state described by the wave function :

$$\psi(\theta,\phi) = \frac{1}{\sqrt{30}}\left(5y_4^0 + y_6^0 - 2y_6^3\right)$$

where $y_l^m(\theta,\phi)$ all the spherical harmonics. The probability of finding the system in a state with $m = 0$ is :

(a) Zero

(b) 2/15

(c) 1/4

(d) 13/15

10. Angular momentum of an atomic electron is :

(a) Quantized in magnitude only

(b) Quantized in direction only

(c) not quantized

(d) Quantized both in magnitude and direction

11. The explicit expression for the operator $\left(\hat{L} - \hat{M}\right)\left(\hat{L} + \hat{M}\right)$ is :

(a) $\hat{L}^2 - \hat{M}^2$

(b) $\hat{L}^2 - \hat{M}^2 + \left(i\hat{M} - \hat{M}\hat{L}\right)$

(c) $\hat{L}^2 - \hat{M}^2 + 2\hat{L}\hat{M}$

(d) $\hat{L}^2 - \hat{M}^2 - 2\hat{M}\hat{L}$

12. A hydrogen atom remains is its ground state when electron :

(a) reside inside the nucleus

(b) escape from the atom

(c) is in its first orbit

(d) does not orbit round but its stationary

13. The potential field of hydrogen atom is :

(a) $v(r) = -\frac{A}{r}$

(b) $v(r) = 0$

(c) $v(r) = Ae^{-r/a_0}$

(d) $v(r) - \frac{\Delta}{r^2}$

14. For $n = 3$ the degenerate eigen function of hydrogen atom are :

(a) 9

(b) 18

(c) 10

(d) 20

15. The value of $\left[L_x, L_y\right]$:

(a) 0

(b) 1

(c) $i\hbar L_z$

(d) None of the above

16. The particle possessing angular momentum requires :

(a) weaker attractive potential to bind it than a particle with no angular momentum.

(b) stronger attractive potential to bind it than a particle with no angular momentum.

(c) equal attractive potential to bind it to a particle with no angular momentum

(d) None of the above

17. When a perturbation of cx^5 is applied in the Hamiltonian of harmonic oscillation, the first order energy correction is :

(a) $\left(n + \frac{1}{2}\right)\hbar\omega$

(b) $\hbar\omega$

(c) $\frac{3}{4}\hbar\omega$

(d) Zero

18. If there are several functions that correspond to the same energy, the system is known as :

(a) Degenerate

(b) Non-degenerate

(c) Both (a) and (b)

(d) None of the above

19. The first order change in energy values for normal Zeeman effect is :

(a) $\frac{e\hbar^2 \mathrm{H}^2}{2\mu c} m_e$

(b) $\frac{e\hbar \mathrm{H}}{2\mu c} m_e$

(c) $\frac{e^2\hbar^2}{2\mu^2 c^2} m_e$

(d) $\frac{e^2\hbar^2}{2\mu c} m_e$

20. Degeneracy of the first excited state of an isolated hydrogen atom is :

(a) 2

(b) 4

(c) 6

(d) 8

Section—B 2 each

(Very Short Answer Type Questions)

Note : Attempt all questions.

1. Write the statement and equation for Rayleigh-Jean's law.
2. Define phase and group velocity.
3. State superposition principle.

4. Write operators for position, momentum, energy and angular momentum.
5. Define spherically symmetric potential.
6. Write down the commutation relation of total angular momentum with its components.
7. Write the expression for first order energy and wave function for non-degenerate level.
8. What do you mean by perturbation of a system ?

Section—C 3 each

(Short Answer Type Questions)

Note : Attempt all questions.

1. Explain Planck quantum hypothesis of black body spectrum.
2. Write *three* conditions for a wave function to be admissible.
3. Discuss completeness of eigen function.
4. Write any *three* properties of Bra and Ket notations.
5. Find the commutation relation of $\left[\mathrm{L}_x, \mathrm{L}_y\right]$ and $\left[\mathrm{L}_x \mathrm{L}_z\right]$.
6. What do you understand by parity ? Deduce the parity of wave function with spherically symmetric potential.
7. Explain the meaning of degenerate state, giving an example from the stationary states of the hydrogen atom.
8. Find the first order perturbed energy for harmonic oscillator if perturbed Hamiltonian $\mathrm{H}' = \frac{1}{2} bx^2$ using energy raising and lowering operator.

Section—D 5 each

(Long Answer Type Questions)

Note : Attempt all questions.

1. State and prove uncertainty principle and explain non-existence of electron in the nucleus using uncertainty principle.

Or

Find the energy levels for one-dimensional square wave potential of finite depth.

2. Explain the matrix theory of harmonic oscillator and find that $E_n = \left(n + \frac{1}{2} \right) \hbar\omega$.

Or

Explain Dirac delta function in detail and also give some representations of Dirac delta function.

3. What do you understand by spin angular momentum ? For spin 1/2, find the expression for general spin angular momentum and Pauli spin matrices. Also give the properties of Pauli spin matrices.

Or

Find the bound state energy levels for three-dimensional square well potential and give interior solutions for arbitrary *l*.

4. Explain first order perturbation theory for degenerate energy levels and prove that perturbation removes the degeneracy.

Or

Using perturbation theory, explain first and second order Zeeman effect without electron spin.