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M.Sc. (Second Semester)
EXAMINATION, May - June, 2022
PHYSICS
Paper First
(Quantum Mechanics - I)

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

Note: Attempt all the sections as directed.

(Section - A)

(Objective/Multiple Choice Questions)

(1 mark each)

Note: Attempt all questions. Choose the correct answer.

1. In the first excited state of a one dimensional harmonic oscillator with angular frequency ω, the energy eigen value is given by:

   (A) $\frac{1}{2}\hbar\omega$

   (B) $\hbar\omega$

   (C) $\frac{3}{2}\hbar\omega$

   (D) $2\hbar\omega$

2. A free particle in one dimension is in a state described by:

   $\Psi(x,t) = A\exp(ipx - iEt)/\hbar + B\exp(-ipx - iEt)/\hbar$

   The probability current density is given by:

   (A) P/m

   (B) $(|A| - |B|)P/m$

   (C) $(|A|^2 - |B|^2)P/m$

   (D) $(|A|^2 + |B|^2)P/m$

3. The threshold frequency of photons for photoelectric emission from a metal of work function 1.6 eV $(\hbar = 6.6\times10^{-34} J.S)$:

   (A) 3.9×10^{14} Hz

   (B) 2.4×10^{13} Hz

   (C) 2.7×10^{9} HZ

   (D) 4.5×10^{12} Hz

4. The length of wave packet is given by:

   (A) $-\lambda^3/\Delta\lambda$

   (B) $\frac{-\lambda^2}{\Delta\lambda}$

   (C) $\lambda^3/\Delta\lambda$

   (D) $\lambda^4/\Delta\lambda$

5. Which of the following wave function can be solutions of Schrodinger's equation for all values of x ?

   (A) $\Psi = A\sec x$

   (B) $\Psi = A\,e^{-x^2}$

   (C) $\Psi = A\tan x$

   (D) $\Psi = A\,e^{x^2}$

6. Energy lowering operator is:

   (A) $(P + im\omega_c^2 x)$

   (B) $(P - im\omega_c^2 x)$

   (C) $(P + im\omega_c x)$

   (D) $(P - im\omega_c x)$

7. Which of the following is a defining equation of Dirac-delta function?

   (A) $\delta(x - x') = 0 \, at \, x = x'$

   (B) $\int_{-\infty}^{\infty} \delta(x - x') = 0$

   (C) $\delta(x - x') = 1 \, at \, x \neq x'$

   (D) $\delta(x - x') = 0 \, at \, x \neq x'$

8. Each hermitian operator has representation as a:

   (A) Diagonal Matrix always

   (B) Null Matrix always

   (C) Matrix always rectangular

   (D) None of the above

9. Eigen value of S_z is

   (A) $m_s z$

   (B) $m_s \hbar$

   (C) $m_z \hbar$

   (D) $m_z S$

10. Which of the following is considered as intrinsic angular momentum

    (A) Spin angular momentum

    (B) Orbital angular momentum

    (C) Total angular momentum

    (D) None of the above

11. Which is property of Pauli's spin matrices

    (A) $\sigma_x^2 = 1$

    (B) $\sigma_y^2 = 0$

    (C) $\sigma_x \sigma_y = 1$

    (D) $\sigma_x \sigma_y = 0$

12. For a spin ½ particles, the expectation values of $S_x \, S_y \, S_z$ (where $S_x \, S_y$ and are S_Z spin operator) is

    (A) $i\hbar^3/8$

    (B) $i\hbar^3/16$

    (C) $-i\hbar^3/8$

    (D) $-i\hbar^3/16$

13. Hydrogen atom in its first excited state behaves as it has:
    (A) A permanent electric dipole moment of magnitude $3ea_0^2$
    (B) A permanent electric quadrupole moment of magnitude $3ea_0$
    (C) A permanent electric dipole moment of magnitude $3ea_0$
    (D) None of the above
14. For first order stack effect in hydrogen the perturbation H will be:
    (A) $eEr\sin\theta$
    (B) $eEr\sin^2\theta$
    (C) $-eEr\cos^2\theta$
    (D) $-eEr\cos\theta$
15. The time independent first order perturbation energy correction for a non-degenerate system gives the expectation value of:
    (A) Zeroth order Hamiltonian
    (B) First order Hamiltonian
    (C) Zeroth order Momentum
    (D) First order Momentum
16. When n = 2, the state of hydrogen is:
    (A) Two fold degenerate
    (B) Non degenerate
    (C) Three fold degenerate
    (D) Four fold degenerate

17. The energy spectra of bound state are:
    (A) Continuous
    (B) Discrete
    (C) Degenerate
    (D) Non-degenerate
18. If $f(x) = +f(-x)$ then the function has:
    (A) Odd parity
    (B) Even parity
    (C) (A) and (B) both
    (D) None of the above
19. In a finite potential well the potential energy outside the box is:
    (A) Zero
    (B) Constant
    (C) Infinite
    (D) Variable
20. The value of spherical harmonics Y_∞ is
    (A) $\sqrt{\frac{3}{4\pi}}\cos\theta$
    (B) $\sqrt{\frac{3}{4\pi}}\sin\theta$
    (C) $\frac{1}{\sqrt{4\pi}}$
    (D) $\sqrt{4\pi}$

Section - B
(Very Short Answer Type Questions)

(2 marks each)

Note: Attempt all questions.

1. Write the statement and equation for Stefan's law.
2. Write four conditions of wave function to be admissible, (without description)
3. What do you understand by completeness of Eigen function?
4. What will be uncertainty in position of electron with energy 1eV?
5. Write only Eigen values of the following :

   S_z, S^2, J_z, J^2
6. Write radial part of Schrodinger equation.
7. Define degenerate state of a system.
8. Write first order perturbing Hamiltonian for Zeemen effect.

Section - C
(Short Answer Type Questions)

(3 marks each)

Note : Attempt all questions.

1. State three inadequacies in classical mechanics.
2. Find the wave function at the surface of infinite potential.
3. Using uncertainty principle find the radius of Bohr's first orbit.
4. Derive continuity equation.
5. Prove that $(\vec{\sigma}.\vec{A})(\vec{\sigma}.\vec{B}) = \overline{A}.\overline{B} + i\overline{\sigma}.(\overline{A}\times\overline{B})$ where σ is Pauli spin matrices.
6. Find the rotational energy Eigen values of the rigid rotates in a fixed plane.

7. Prove that $[L_z L_x] = i\hbar Ly$

   $[L^2, L_z] = 0$
8. Explain occurrence of permanent electric dipole moment.

Section - D
(Long Answer Type Questions)

(5 marks each)

Note: Attempt all questions.

1. State and prove Ehrenfest theorem.

   OR

   Solve the Schrodinger equation for one dimensional harmonic oscillator and find energy Eigen value and normalized wave function.
2. Explain Heisenbey equation of motion. **(5)**

   OR

   (A) Find the states with minimum values of uncertainty product. **(3)**

   (B) Explain raising and lowering operator. **(2)**
3. Derive Clebsch Gordan coefficient for $J_1 = J_2 = ½$

   OR

   Solve the radial part of Schrödinger's is equation for the hydrogen atom and obtain the energy Eigen value. Explain the degeneracy in the spectra.
4. What do you mean by perturbation theory? Discuss the perturbation theory for non degenerate levels in first and second orders.

   OR

   Explain first order stark effect in hydrogen and find perturbed energy levels.