Reg. No .... Name ....

M. Sc DEGREE END SEMESTER EXAMINATION - MARCH 2020

SEMESTER 2 : PHYSICS

COURSE : **16P2PHYT06 : QUANTUM MECHANICS -1**

(For Regular - 2019 Admission & Supplementary 2018/2017/2016 Admissions)

Time : Three Hours Max. Marks: 75

Section A

Answer All the Following (1 marks each)

1. The dispersion of the observable A is given by

   a. $(\Delta A)^2$ b. $\langle A^2 \rangle - \langle A \rangle^2$ c. $\langle A \rangle^2 - \langle A^2 \rangle$ d) ΔA

2. For the quantum mechanical simple harmonic oscillator, one can obtain the third excited state by

   a) $\frac{a^{\dagger^3}}{\sqrt{3}}|0\rangle$ b) $\frac{a^{\dagger}}{\sqrt{3!}}|2\rangle$ c) $\frac{a^{\dagger^3}}{\sqrt{3!}}|0\rangle$ d) $\frac{a^{\dagger}}{\sqrt{3}}|2\rangle$

3. An electron in the $|+\rangle$ state is in the magnetic field $B_z\hat{k}$, then $\frac{dSz}{dt}$ is

   a) $\frac{e}{mc}$ b) 0 c) μ d) constant in z

4. If L is the angular momentum operator, x and p the position and momentum operators then

   a) $L^2 = x^2p^2 - (x \cdot p)^2 + i\hbar x \cdot p$ b) $L^2 = x^2p^2 + (x \cdot p)^2 - i\hbar x \cdot p$ c) $L^2 = x^2p^2 - i\hbar(x \cdot p) + x \cdot p$ d) $L^2 = x^2p^2 + i\hbar(x \cdot p) - x \cdot p$

5. The variational principle states that the ground state energy of the system is give by

   a) $E_1 \leq \langle H \rangle$ b) $E_1 = \langle H \rangle$ c) $E_1 \geq \langle H \rangle$ d) $E_1 = E_0$

(1 x 5 = 5)

Section B

Answer any 7 (2 marks each)

6. What do you mean by a pure ensemble?
7. Write a note on simultaneous eigen kets.
8. Show that commuting operators possess simultaneous eigen functions
9. Sketch graphs of $\psi(x)$ and $|\psi(x)|^2$ for the ground state of the one-dimensional simple harmonic oscillator.
10. What are creation and annihilation operator? How are they related to the Number operator?
11. What are energy eigen kets?
12. Why does the angular momentum operators of different no-interacting particles commute.
13. If $|jm\rangle$ denotes the simultaneous eigenkets of J^2 and J_z then write the eigen value equation of J^2 and J_z.
14. Write Ritz variational principle.
15. State the criterion for the validity of WKB approximation.

(2 x 7 = 14)

Section C
Answer any 4 (5 marks each)

16. Express the momentum operator in position space.
17. Prove Schwarz inequality
18. If a and a^{+} are the annihilation and creation operator of a quantum mechanical simple harmonic oscillator show that

$$a|n\rangle = \sqrt{n}|n-1\rangle \text{ and } a^{+}|n\rangle = \sqrt{n+1}|n+1\rangle.$$

19. Show Ehrenfest's theorem is the quantum mechanical analogue of Newton law of nation.
20. Obtain the commutation relation $[J^2, J_x]$.
21. Evaluate the first and second order corrections to the energy of the $n = 1$ state of an oscillator of mass m and angular frequency ω subjected to a potential given by

$$V(x) = \frac{1}{2}m\omega^2x^2 + bx$$

Here b is independent of x and b and $\frac{1}{2}m\omega^2x^2 >> bx$.

(5 x 4 = 20)

Section D
Answer any 3 (12 marks each)

22.1. Discuss the uncertainity principle and show that the minimum uncertainity wave function is a Gaussian.

OR

2. For a one – dimensional simple harmonic oscillator (SHO), using creation and annihilation operators, show that

$$(\Delta x)(\Delta p) = \left(n + \frac{1}{2}\right)\hbar.$$

Also draw the $\psi(x)$ and $|\psi(x)|^2$ for the first three states of the SHO.

23.1. (i) Discuss the properties of the rotation operator.
(ii) A spin $\frac{1}{2}$ system initially in the state $|\alpha\rangle$ was rotated by ϕ about the z-axis. Find the expectation value of S_x, S_y and S_z with respect to the rotated state $|\alpha\rangle_R$.

OR

2. Discuss addition of angular momenta with a specific example. What are Clebsch-Gordon coefficients?

24.1. Discuss the time independent perturbation theory for the non degenerate case and obtain an expression for the first order energy correction.

OR

2. Discuss variational method as applied to Bound problems with one example.

(12 x 3 = 36)