St. Philomena's College (Autonomous), Mysore
Question Bank
Programme: M. Sc. Physics
II Semester
Course Title: QUANTUM MECHANICS-I-HC
Course Type: Hard Core
Q.P Code58102

3 Marks Question

1. Write a note on symmetric and anti symmetric wave functions. (3)

4 Marks Questions

1. Evaluate $\hat{P}^2{}_+$, $\hat{P}^2{}_-$, $\hat{P}_+\hat{P}_-$, $\hat{P}_-\hat{P}_+$.
2. In the conteaxt of spin half particle in SGz device (Stern Gerlac device with inhomogenious magnetic field in z-direction), discuss vector representation of Kets and Bras.
3. Evaluate the $|P\rangle$ for the Gaussian wave packet.

6 Marks Questions

1. Write the expression for the amplitude of a particle to go from source to screen in a hypothetical Young's double and triple slit experiment.
2. Express an arbirtary spin state (of a spin half particle) $|\psi\rangle$ as linear combination in Sz basis and give interpretation for the coefficients in linear combination.
3. Obtain the soloution for coefficients in linear combination.
4. Obtain matrix representation of projection operators $\hat{P}_+$ and $\hat{P}_-$ and prove the completeness relation.
5. Prove that the stationary stales of the infinite Squarewell potential are mutually orthogonal.
6. Discuss the physical and mathematical properties of the separable solutions of the Schrodinger equation.
7. Evaluate $\sigma_i\sigma_j + \sigma_j\sigma_i$ where σ_{ij} are the Pauli spin matrices and can take on the values $1 = x$, $2 = y$ and $3 = z$. Also prove that for $i = j$, $\sigma_x^2 + \sigma_y^2 + \sigma_z^2$, and while for $i \neq j$, $[\sigma_i, \sigma_j] \neq 0$.
8. Obtain the the second order correction to energy and eigenfunction for a nondegenerate system under perturbation.
9. Explain the Weak-field Zeeman Effect.
10. Apply variational principle for a simple harmonic Oscillator by taking appropriate trial function to evaluate upper bound for ground state energy.
11. Obtain the energy levels of the s state of an electron that is bound to a 'Ze' nucleus using the WKB method.

7 Marks Questions

1. If the generator of rotations Jz obeys eigen state condition $Jz\,|\pm z\rangle = \frac{\hbar}{2}\,|\pm z\rangle$. Show that the rotation operator $R(\frac{\pi}{2}k)\,|+x\rangle = e^{\frac{\pi}{4}}\,|+y\rangle$.

2. Discuss identity and projection operators and arrive at completeness relation of projection operators.

3. Discuss the concept of rotation operator and show that rotation operator is unitary.

4. Express rotation operator using generator of rotation $\hat{J}_z$ (z component of spin angular momentum of a particle). Show that $\hat{J}_z$ is hermitian.

8 Marks Questions

1. Define time evolution operator and arive at Schrodinger equation using time evolution operator.

2. Express expectation value in matrix representation.

3. Write short notes on any two of the following:

   (a) The Schrodinger Picture

   (b) The Heisenberg Picture

   (c) The interaction picture

4. Arrive at the relativistic correction to the energy of hydrogen spectra using nondegenerate perturbation theory.

5. Estimate the ground state energy of hydrogen atom using the trial wave function $\psi(r) = Ae^{-\alpha}r$.

6. Solve the time independent Schrodinger equation and obtain the Eigenkets and Eigenvalues for a free particle and hence explain the concept of phase and group Velocities.

7. Discuss the square well potential for scattering states with the physical interpretation and suitable boundary conditions.

8. Discuss the motion of a particle in a finite square well for bound state and derive the admissible solutions of the time independent Schrodinger equations.

9. Obtain the Eigenvalues of L^2 and L_z operators using the operator $L_{\pm} = L_x \pm iL_y$.

10. Apply the WKB method to calculate the energy eigenvalues of one dimensional harmonic oscillator.

9 Marks Questions

1. Express $|+x\rangle$ and $|+y\rangle$ as linear combination in Sz basis. Additionally if $|\,\langle +y| + x\rangle\,| = 1/2$, obtain the final form of $|+x\rangle$ and $|+y\rangle$.

2. Discuss the concept of Expectation value and Uncertainty. Show that expectation $|Sz\rangle = 0$, and uncertainty $\Delta Sz = \frac{\hbar}{2}$.

3. Obtain the matrix representation of operator $\hat{J}_z$ and show that $\hat{J}_z$ can be expressed using projection operators.

4. Discuss matrix representation of rotation operator and its application in change of basis.

5. Discuss the translational operator in one dimensional position basis.

6. Discuss generator of translations and its properties and arrive at Ehrenfest's theorem.
7. Discuss the momentum operator in the position basis.
8. Separate the Schrodinger equation into time dependent and time-independent parts and obtain the steady state Schrodinger equation.
9. Discuss the motion of a particle in an infinite square well potential for bound state and derive the admissible solutions of the time-independent Schrodinger equation.
10. Evaluate the Clebsch- Gordon coefficients for the addition of two angular momenta $j_1 = 1/2$, $j_1 = 1/2$.
11. Discuss momentum space and show that $\langle p|\psi\rangle$ and $\langle x|\psi\rangle$ form a Fourier transform pair.

10 Marks Questions

1. Discuss uncertainty relations in the context of angular momentum.
2. Discuss position eigen states and the wave function with necessary interpretations.
3. Discuss Gaussian wave packet.
4. Analyze the scattering states for a particle in the potential $V(x) = -\alpha\delta(x)$, where $\alpha > 0$ and $\delta(x)$ is the Dirac delta function. Show that the sum of reflection and transmission coefficients is unity.
5. Separate the time independent Schrodinger equation in spherical polar coordinates and identify the radial and angular parts.
6. Solve the radial part of Schrodinger's equation for the hydrogen atom to obtain the energy eigenvalues and eigen functions corresponding to $R_{10}(r)$.
7. Explain the Zeeman effect as an example of nondegenerate pertubation theory.
8. State the general variational principle and analyze the Rayleigh-Ritz variational method to estimate the ground state energy of a system with Hamiltonian H.
9. Explain the Gamow's model for potential energy of an alpha particle in a radioactive nucleus using the quasi-classical approximation.

12 Marks Questions

1. Discuss matrix representation of the operator $\hat{A}$ and its adjoint $\hat{A}^\dagger$ in Sz basis.
2. Obtain the Eigenkets and energy Eigenvalues of a simple harmonic Oscillator using raising and lowering operators.
3. Solve the Schrodinger equation for the harmonic oscillator potential analytically and obtain its energy levels.
4. Obtain the second order correction for a two fold degenerate system undergoing time independent perturbation.
5. Discuss time independent perturbation theory for a nondegenerate system and hence obtain the first order correction to energy and eigenfunction.
6. Obtain an expression for the energy of spin orbit interaction using the time Independent perturbation theory.

7. Estimate the ground state energy of helium atom using the Variational method.
8. Derive the Bohr–Sommerfeld quantization rule using the WKB approximation.

14 Marks Question

1. Evaluate the bound and Scattering state solutions of Schrodinger equation for a particle confined to the potential. Where and is the Dirac's delta function.