M.Sc. Physics Examination

Semester - 2

Paper : PhysC-202, Quantum Mechanics

Paper Code- 4657

Time : 2 Hours 30 min | Oct-2016 | Maximum Marks 70

Notes:

1.	(a) Compute $< x >, < p >, < x^2 > and < p^2 >$ for the ground state of harmonic oscillator. Check the uncertainty principle for this case. (b) Evaluate the commutator $[x^n, p] = ni\hbar x^{n-1}$ (c) Explain physical interpretation of eigen values and eigen functions. Justify the Eigen values of a self-adjoint operator is real.	[5] [3] [6]
OR		
1.	(a) The normalized state of free particle is represented by a wave function $\psi(x,0) = Ne^{-(x^2/2a^2)+ik_0x}$ Find the factor N. In what region of space the particle is most likely to be found. (b) Calculate the ground state energy of Harmonic oscillator by operator method. (c) Define: (i) Degeneracy, (ii) Dirac delta function and (iii) Hilbert space.	[4] [7] [3]
2.	(a) Work out the following commutator relations (i) $[L_x, [L_y, L_z]]$ (ii) $[L_y^2, L_x]$ (iii) $[J^2, J_\pm]$ (b) Explain Spin. Write the matrix operators for S^2, S_x, S_y, S_z, S_+ and S_-. (c) Express p^2 and ∇^2 in terms of angular momentum operator (L^2). Write Schrodinger equation in form of L^2.	[6] [4] [4]
OR		
2.	(a) Write expression of aa^+ and a^+a. (b) Find the expectation value of the energy when the state of the Harmonic oscillator is described by the following wave function $\Psi(x,t) = \frac{1}{\sqrt{2}}[\Psi_0(x,t) + \Psi_1(x,t)]$ where $\Psi_0(x,t)$ *and* $\Psi_1(x,t)$ are the wave function for the ground state and first excited state respectively. (c) For the particle in a spherical symmetric potential, derive the equation for the angular part of Schrodinger equation. (d) Quantum Mechanically, find out the value of $(\vec{L} X \vec{L})^2$. Here, $\vec{L}$ is Angular momentum.	[2] [4] [4] [4]
3.	(a) Derive the formula for the first order correction to the energy for Degenerate energy levels. (b) A simple harmonic oscillator of mass m and angular frequency ω is perturbed by an	[6] [5]

	additional potential $\frac{1}{2}\, bx^2$. Obtain the second order correction to the groung state energy. (c) Why the hydrogen atom in the ground state does not show a first-order Stark effect?	[3]
OR		
3.	(a) What is Harmonic perturbation? Prove that the transition probability is proportional to the square of the matrix element of the amplitude of the harmonic perturbing term between states n & k. (b) A rigid rotator in a plane is acted on by a perturbation represented by$H' = \frac{V_0}{2}(3cos^2\emptyset - 1)$, where V_0 is a constant. Calculate the ground state energy up to the first and second order in the perturbation. (c) Which of the following transitions are electric dipoles allowed? – Justify also. (i) $3s \rightarrow 4s$, (ii) $1s \rightarrow 2p$, (iii) $3d \rightarrow 4f$	[6] [5] [3]
4.	(a) Explain how to study the emission of alpha (α) – particles by nuclei with help of WKB approximation. (b) Prove that T + R = 1, here T is transmission co-efficient and R is reflection co-efficient. (c) State Variational principle. Optimize the trial function $e^{-ar}$and evaluate the ground state energy of the hydrogen atom.	[4] [2] [8]
OR		
4.	(a) Write the Schrodinger equation of a particle confined to the positive x-axis with potential energy V(x) = mgx. For $\Psi(0) = 0$, $\Psi(x) \rightarrow 0$ as $x \rightarrow \infty$. Obtain the ground state energy using variational method. (b) Discuss briefly the validity conditions of WKB approximation. (c) Explain how to solve barrier penetration problem by WKB approximation method.	[6] [4] [4]
5.	(a) What is scattering amplitude? How is it related to differential scattering cross-section? (b) In a scattering experiment, one need consider partial waves up to $l = kr_0$, where r_0 is the range of the potential – Justify. (c) Calculate the scattering amplitude for a particle moving in the potential $V(r) = V_0\left(\frac{c-r}{r}\right) exp\left(-\frac{r}{r_0}\right)$, where c, V_0 and r_0 are the constants.	[6] [4] [4]
OR		
5.	(a) Deduce the first Born approximation formula for the scattering amplitude for weak potentials. (b) Define scattering length. How is it related to zero energy cross-section? (c) State and derive the relation connecting the differential cross-section in laboratory coordinate system and centre of mass coordinate system.	[6] [4] [4]