RAN-1903080103010001

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M.Sc. (Sem.-III) Examination October - 2025

Physics : PH - 531 (Quantum Mechanics - II)

Time: 3 Hours] **[Total Marks: 70**

સૂચના : / Instructions

(1) ઉપરોક્ત દર્શાવેલ વિગતો ઉત્તરવહી પર અવશ્ય લખવી.
Fill up strictly the above details on your answer book

(1) Symbols used have their usual meaning.

(2) Figures to the right indicate full marks.

Seat No.:

Student's Signature

Q.1. Attempt any two questions out of the (a), (b) and (c) below.

(a) (i) Solve radial equation for free particle in three dimensions. **5**

(ii) Write Hydrogen energy levels and their degeneracies when the electron spin is ignored for n = 1. 2. 3. 4. **4**

(b) (i) Derive the Hamiltonian of a particle of mass μ and charge q moving in a central potential $V(r)$ under the influence of a uniform magnetic field $\vec{B}$. **5**

(ii) Write note on: Normal Zeeman effect **4**

(c) (i) Derive the energy eigenvalue expression for a particle of mass m in a three-dimensional isotropic harmonic oscillator using the radial Schrodinger equation. **5**

(ii) In the case of three-dimensional Isotropic Harmonic Oscillator, show that the second excited state is sixfold degenerate and its energy is $\frac{7}{2}\hbar\omega$. **4**

Q.2. Attempt any two questions out of the (a), (b) and (c) below.

(a) (i) Derive the expression for the rotation operator $\widehat{R_n}(\phi)$ corresponding to a finite rotation of angle ϕ about $\hat{n}$ for spinless system. **5**

(ii) Write note on: Irreducible Spherical Tensors **4**

(b) (i) Describe Isospin and discuss its algebra. **5**

(ii) Prove that $j^2_{min} = (j_1 - j_2)^2$ in the case of addition of two momenta $\vec{J}_1$ and $\vec{J}_2$. **4**

(c) (i) For the case $j = l + \frac{1}{2}$, Determine the Clebsch-Gorden coefficients associated with coupling of orbital angular momentum l and spin $s = \frac{1}{2}$ particle. **5**

(ii) Explain the Clebsch-Gorden Coefficients along with their physical significance. **4**

Q.3. Attempt any two questions out of the (a), (b) and (c) below.

(a) (i) Prove that **5**

a. Permutation operator does not commute

b. Two successive applications of permutations operator leave the wave function unchanged.

(ii) Specify the symmetry of functions with justification **4**

a. $\varphi(x_1, x_2) = -\dfrac{3(x_1 - x_2)}{2(x_1 - x_2)^2 + 7}$

b. $\chi(x_1, x_2, x_3) = 6x_1x_2x_3 + \dfrac{x_1^2 + x_2^2 + x_3^2 - 1}{2x_1^3 + 2x_2^3 + 2x_3^3 + 5}$

(b) (i) Explain Pauli's Exclusion Principle and Boson condensation. **5**

(ii) Write Note on: Composite particles **4**

(c) (i) Discuss Exchange degeneracy. **5**

(ii) Write the ground state electronic configuration of the Aluminum (Al) atom. From this configuration, determine all the possible spectroscopic terms and, using Hund's rules, identify the lowest energy ground state. **4**

Q.4. Attempt any two questions out of the (a), (b) and (c) below.

(a) (i) Derive second order perturbation equation and solve it for Non-degenerate perturbation theory. **4**

(ii) Derive the expression for the energy correction to the fine structure of the hydrogen atom arising from spin–orbit coupling. **4**

(b) (i) Describe the variational method to determine the ground state energy. **4**

(ii) Use the variational method to estimate the ground state energy of the hydrogen atom. **4**

(c) (i) Describe the WKB method for approximate treatments of system with slowly varying potentials. **4**

(ii) Calculate the energy levels of a one-dimensional harmonic oscillator using the WKB method. **4**