2018-19

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PG CBCS

M.Sc. Semester-III Examination, 2019

M.Sc. PHYSICS

Paper Code: PHS-301

Full Marks : 40 **Time: 2 Hours**

Use Separate scripts for Group A & Group B

Group A

(Quantum Mechanics-III)

1) Answer any <u>two</u> questions of the following: **(2 x 2 = 4)**

a) Two identical spin 1/2 particles are enclosed in 1D infinite potential box of length L with rigid walls at x=0 and x=L. Find first excited state energy and wave function if two particle system is in a single spin state.

b) Suppose in a strange Universe the electron spin 3/2 rather spin 1/2 but all other physics are the same as in our Universe. What are the atomic numbers of the lightest two inert gases?

c) Show that in an electromagnetic radiation field, the electric field interacts more strongly with the atom than the magnetic term and the perturbing Hamiltonian is $eE_0 \cos \omega t\, \hat{e}.\vec{r}$, $\hat{e}$ is the polarization vector.

d) Find the phase shift δ_0 for s wave by the potential

V(r)=∞ $for\ 0 \leq r \leq a$

=0, r>a

2) Answer any <u>two</u> questions of the following: **(4 x 2 =8)**

a) Show that the s matrix is unitary when the Hamiltonian is Hermitian.

b) A Hydrogen atom in the ground state is subjected to an electric field $E = E_0 e^{-t/\tau}, t > 0$ along z axis. Calculate the probability for transition to the |210> state.

c) Distinguish between adiabatic and sudden approximation in time dependent perturbation theory.

d) Find the scattering cross-section for scattering of a particle of mass m by the s-function potential.

$$V(\vec{r}) = g\delta(\vec{r})$$

where g = constant

3) Answer any <u>one</u> questions: **(8 x 1 =8)**

a) i) Two electrons move in a central field. Consider the electrostatic interaction $\frac{e^2}{|\vec{r_1}-\vec{r_2}|}$ between the electrons as a perturbation. Find the first order energy shifts for the states of the 1s2s configuration in terms of unperturbed quantities and matrix elements of the interaction $\frac{e^2}{|\vec{r_1}-\vec{r_2}|}$. (4)

ii) Derive Fermi's golden rule, in case of harmonic perturbation. (4)

(P.T.O.)

b) i) If $V(r) = \frac{-Ze^2}{2R}\left(3 - \frac{r^2}{R^2}\right) for\ 0 < r < R$

$\frac{-Ze^2}{r} e^{-ar} for\ R < r < \infty$

Show that form factor F(q) for high energy elastic scattering is given by

$$F(q) = \left(\frac{3}{q^2R^2}\right)\left(\frac{\sin qR}{qR} - \cos qR\right)$$

where q = momentum transfer wave vector. (5)

ii) Obtain the expression of a plane wave in terms of spherical wave. (3)

Group B

(Statistical Mechanics - I)

4. Answer any <u>two</u> questions of the following: (2× 2 = 4)

a) An ensemble of N three level system with energies E= $-\epsilon_0, 0, \epsilon_0$ is in thermal equilibrium at temperature T. If $\beta = (k_B T)^{-1}$ and $\beta\varepsilon_0 = 2$, find the probability of finding the system in the level $\epsilon = 0$.

b) Define pure state. Prove that a pure state vector can not change into a non-pure or mixed state.

c) If for N localized distinguishable freely oriented dipoles $E = -\sum_{i=1}^{2} \vec{\mu_i}.H$ Find the canonical partition function.

d) What do you understand by negative temperature? Cite at least one of its application.

5. Answer any <u>two</u> questions of the following: (4 x 2 = 8)

a) The Hamiltonian of a system of N non-interacting spin ½ particle is H=$-\mu_0 B \sum S_i^z$, where $S_i^z = \pm 1$ are components of ith spin along an external magnetic field B. At a temperature T such that $\exp(\frac{\mu_0 B}{k_B T}) = 2$ Show that the specific heat per particle is $\frac{16}{25} k_b (\ln 2)^2$. (4)

b) If ρ_1 and ρ_2 be a pair of density matrixes, prove that $\hat{\rho} = r\widehat{\rho_1} + (1-r)\widehat{\rho_2}$ is a density matrix for all real number r such that $0 \leq r \leq 1$ (4)

c) The density matrix of a system is

$$\rho = \frac{1}{4}\begin{pmatrix} 2 & 1 & 1 \\ 1 & 1 & 0 \\ 1 & 0 & 1 \end{pmatrix} \text{ and } A = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & -1 \end{pmatrix}$$

Calculate ΔA.

d) Calculate the expression of specific heat for a two dimensional quantum harmonic oscillator. (4)

6. Answer any <u>one</u> questions of the following: **(8 x 1 = 8)**

a) i) Show that for a system in the canonical ensemble

$$< (\Delta E)^3 \geq K^2\{T^4 \left(\frac{\partial C_V}{\partial T}\right)_V + 2T^3 C_V\}$$ (4)

ii) In a spin system 75% spin is in upward direction and 25% spin in downward direction. Calculate density matrix and also calculate P_x, P_y, P_z (Polarization vector). (4)

b) i) Calculate the density matrix for a particle of mass m in an infinite potential box of volume V in co-ordinate representation. (5)

ii) Prove that grand potential

$$\Omega = U - TS - \mu N$$

where the symbols have usual meanings. (3)

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