

2018-19

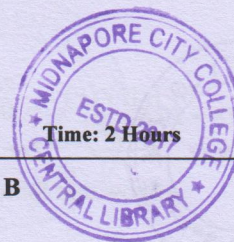
PG CBCS

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 &amp; Group B

Group A

(Quantum Mechanics-III)

- 1) Answer any two questions of the following: (2 x 2 = 4)
- 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.
  - 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?
  - 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  $eE_0 \cos \omega t \hat{e} \cdot \vec{r}$ ,  $\hat{e}$  is the polarization vector.
  - Find the phase shift  $\delta_0$  for s wave by the potential  

$$V(r)=\infty \text{ for } 0 \leq r \leq a$$

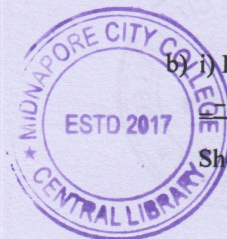
$$=0, r>a$$
- 2) Answer any two questions of the following: (4 x 2 = 8)
- Show that the s matrix is unitary when the Hamiltonian is Hermitian.
  - A Hydrogen atom in the ground state is subjected to an electric field  $E = E_0 e^{-t/\tau}$ ,  $t > 0$  along z axis. Calculate the probability for transition to the  $|210\rangle$  state.
  - Distinguish between adiabatic and sudden approximation in time dependent perturbation theory.
  - 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  $g = \text{constant}$
- 3) Answer any one questions: (8 x 1 = 8)
- 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)
  - Derive Fermi's golden rule, in case of harmonic perturbation. (4)
- (P.T.O.)



(2)



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

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

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 two questions of the following:

(2 × 2 = 4)

- 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  $\beta \epsilon_0 = 2$ , find the probability of finding the system in the level  $\epsilon = 0$ .
- Define pure state. Prove that a pure state vector can not change into a non-pure or mixed state.
- If for  $N$  localized distinguishable freely oriented dipoles  $E = -\sum_{i=1}^N \vec{\mu}_i \cdot \vec{H}$ . Find the canonical partition function.
- What do you understand by negative temperature? Cite at least one of its application.

5. Answer any two questions of the following:

(4 × 2 = 8)

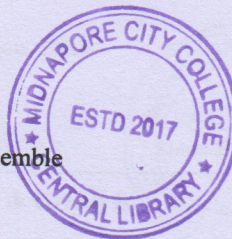
- The Hamiltonian of a system of  $N$  non-interacting spin  $\frac{1}{2}$  particle is  $H = -\mu_0 B \sum S_i^z$ , where  $S_i^z = \pm 1$  are components of  $i^{\text{th}}$  spin along an external magnetic field  $B$ . At a temperature  $T$  such that  $\exp\left(\frac{\mu_0 B}{k_B T}\right) = 2$ . Show that the specific heat per particle is  $\frac{16}{25} k_B (\ln 2)^2$ .
- If  $\rho_1$  and  $\rho_2$  be a pair of density matrixes, prove that  $\hat{\rho} = r\hat{\rho}_1 + (1-r)\hat{\rho}_2$  is a density matrix for all real number  $r$  such that  $0 \leq r \leq 1$ .
- The density matrix of a system is  $\rho = \frac{1}{4} \begin{pmatrix} 2 & 1 & 1 \\ 1 & 1 & 0 \\ 1 & 0 & 1 \end{pmatrix}$  and  $A = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & -1 \end{pmatrix}$ . Calculate  $\Delta A$ .
- Calculate the expression of specific heat for a two dimensional quantum harmonic oscillator.

(4)

(P.T.O.)



(3)



6. Answer any one questions of the following:

(8 x 1 = 8)

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

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

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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