See. 2017-18

Third Semester Examination-2018

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)

Answer question number 1 and 2 and any one from the rest.

1) Answer any three questions. (2 x 3 = 6)

a) A particle of charge q and mass m is moving in a one dimensional harmonic oscillator potential of frequency ω_0. Show that the spontaneous emission rate for a transition from an excited state |n> to the ground state is proportional to $\omega_0^2 q^2/m$.

b) The excited electronic configuration $1s^*2s^*$ of the helium atom can exist as either single or a triplet state. Write the spatial wave function for these state and tell which state has lower energy.

c) Write and plot gėrade and ungerade state of a H_2^+molecular ion.

d) Consider the electric scattering of 50 MeV neutrons from a nucleus. The phase shifts measured in this experiment are negligible ($\delta_l = 0$) for l$\geq$ 6. Estimate the radius of the nucleus.

e) Which of the following transitions are electric dipole allowed?

i) 1s → 2s

ii) 1s → 2p

iii) 2p → 3d

iv) 3s → 5d

2) Answer any one (4x1 = 4)

a) Two non-interacting particles are placed in a one dimensional infinite potential well. Write the two lowest total energies, the degeneracy of each of the two energy levels and the possible two particle wave functions if the particles are

i) Distinguishable spin ½ particles

ii) Identical spin ½ particles.

b) Consider a particle of mass m, energy E, scattering from the spherically symmetric potential B$\delta(r-a)$, where B and aareconstants. In case of very low energy scattering ($\lambda > a$), find the differential scattering cross section.

3) a) Establish a relation between the scattering amplitude and differential scattering cross-section. (4)

b) Calculate in the Born-approximation the scattering amplitude for neutron-neutron scattering for the interaction potential V(r) =$V_0\frac{e^{-\alpha r}}{r}$

assuming the scattering vanishes for triplet spin state. Evaluate the differential scattering cross section for an unpolarised initial state (random spin orientation).(6)

4) a) Solve the two state system for the time independent perturbation assuming that $c_a(0) = 1$ and $c_b(0) = 0$ and $H_{ii}^{*} = 0$.
Check that $|c_a(t)|^2 + |c_b(t)|^2 = 1$. (5)

b) A hydrogen atom in the ground state is placed in an electric field $\vec{E} = E_0 e^{-\gamma t}\hat{z}$. Find the first order probability for the atom to be in any of the n = 2 state after a long time.
[Given $\psi_{100} = \frac{1}{\sqrt{\pi a^3}} e^{-r/a}$, $\psi_{210} = \frac{1}{\sqrt{32\pi a^3}} \frac{r}{a} e^{-r/2a}\cos\theta$ and $\int_0^{\infty} x^n e^{-ax} dx = \frac{n!}{a^{n+1}}$]
(5)

Group B

(Statistical Mechanics - I)

Answer question number 5 and any one from the rest

5) Answer any five bits. $(2 \times 5 = 10)$

a) A linear simple harmonic oscillator has mass m and frequency ν. Calculate the number of micro-state between the energy range E and E+ δE.

b) A one-dimensional random walker takes steps to left or right with equal probability. Find the probability that the random walker starting from origin is back to origin after N even number of steps.

c) If for N localized distinguishable freely orientable dipoles

$E = - \sum_{i=1}^{N} \vec{\mu_i} \cdot \vec{H}$

Find the canonical particle function.

d) If $P = \begin{pmatrix} 1/4 & 3/4 \\ 3/4 & 3/4 \end{pmatrix}$

Is it acceptable density matrix ?

e) If <E> = $- \epsilon N \tanh \beta E$, where $\beta = 1/k_B T$, Find C_V.

f) Prove that pure state remain always in pure state.

g) Calculate the partition function of an ultra-relativistic gas governed by the Hamiltonian

$H(p_v, q_v) = \sum_{v=1}^{N} |\overline{p_v}| c$

h) A system consists of three spin ½ particles, the z component of whose spins $S_z(1)$, $S_z(2)$ and $S_z(3)$ can take any value +1/2 and -1/2. The total spin of the system is $S = S_z(1) + S_z(2) + S_z(3)$.

Find the total number of micro-states for this system.

6. a) For a particle of mass m and total energy E moving in a spherical symmetrical potential by $V(r) = a\, r^2$ where a is a constant.

Find the number of micro-states. (5)

b) Calculate the specific heat at constant value for three dimensional quantum harmonic oscillator. (5)

7. a) Deduce the equation of state for ideal Bose and Fermi-gas using grand canonical partition function.

b) If the density matrix $\rho = \frac{1}{4}\begin{pmatrix} 2 & 1 & 1 \\ 1 & 1 & 0 \\ 1 & 0 & 1 \end{pmatrix}$ and $J_Z = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & -1 \end{pmatrix}$

Show that $\Delta J_z = 0.829$ (5)

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