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PG CBCS

M.Sc. Semester-III Examination, 2022

PHYSICS

PAPER: PHS 301

(QUANTUM MECHANICS – III & STATISTICAL MECHANICS – I)

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

Write the answer for each unit in separate sheet

UNIT- PHS 301.1
QUANTUM MECHANICS – III

GROUP-A

1. Answer any TWO from the following questions: **2×2=4**

a) Explain the Laporte selection rule.

b) Show that an attractive potential leads to positive phase shifts whereas a repulsive potential to negative phase shifts.

c) Prove that it is impossible to construct a completely anti-symmetric spin function for three electrons.

d) Distinguish between adiabatic and sudden approximation in perturbation theory.

GROUP-B

2. Answer any TWO from the following questions: **2×4=8**

a) Write down the zeroth-order wave function for the 1s2s excited state of the $_2He^4$ atom.

b) Consider a system of two spin half particles in a state with total spin quantum number S=0. Find the eigen value of the spin Hermitian $H = A\vec{S}_1 \cdot \vec{S}_2$ where A is positive constant in this state.

c) Consider a large number of Fermions of mass m are confined in a cubical box of size L. Find the number of Fermions with energy less than E_F.

d) If $V(r) = V_0 \exp(-\alpha r)/r$ where V_0 and α are constant. Show that differential scattering cross section is independent of θ and ϕ for low energy.

GROUP-C

3. Answer any ONE from the following questions: **1×8=8**

a) An electron is subjected to a static magnetic field $\vec{B}_0 = B_0\hat{z}$ and occupies the spin eigen state $|\uparrow\rangle$. At a given moment $(t = 0)$ an additional time-dependent, a spatially uniform magnetic field $\vec{B}_1(t) = B_1(cos\,\omega t\,\hat{x} + sin\,\omega t\,\hat{y})$ is turned on. Calculate the probability of finding the electron with its spin along the negative z-axis at $t > 0$. 8

b) N identical spin half particles are subject to one dimensional simple harmonic potential. What is the ground state energy? What is the Fermi energy? What is the ground state energy if we ignore the mutual interaction and assume N to be very large. (3+3+2)

UNIT- PHS 301.2
STATISTICAL MECHANICS - II

GROUP-A

1. Answer any TWO of the following questions: 2×2=4

a) Prove that pure state remains pure always.

b) Consider two different systems each with three identical non-interacting particles. Both have single-particle states with energies ε_0, $3\varepsilon_0$ and $5\varepsilon_0$ (ε_0>0). One system is populated by spin $-\frac{1}{2}$ fermions and the other by bosons. What is the value of $E_F - E_B$ where E_F and E_B are the ground state energies of the fermionic and Bosonic systems respectively?

c) A system of N non-interacting classical particles, each of mass m is in a two-dimensional harmonic potential of the form $V(r)=\alpha(x^2+y^2)$, α is a positive constant. Calculate the canonical partition function of the system at the temperature T.

d) If the canonical partition function $Q = \sum_n e^{-\beta E_n}$. Evaluate $< E^2 >$ in terms of Q.

GROUP-B

2. Answer any TWO of the following questions: 2×4=8

a) What is partition function? Consider N number of particle in 3-D. Calculate its partition function.

b) Discuss the energy fluctuation in canonical ensemble.

c) Write down the relation between entropy and microstate of a system. Three particles are in volume V and total energy 4ϵ. The energy levels are 0ϵ, 1ϵ, 2ϵ and 3ϵ. Calculate the entropy, when the particles are (i) indistinguishable and (ii) distinguishable. There is no restriction having number of particle in each energy level.

d) Find out the expression for Internal Energy and pressure for 2-D Fermi gas.

GROUP-C

3. Answer any ONE of the following questions: 1×8=8

a) (i) The Hamiltonian of a system of 3 spins is $H = J(S_1S_2 + S_2S_3)$ where $S_i = \pm 1$for i=1,2,3. Find out its canonical partition function; (ii) Prove that $\langle f \rangle = Tr(\rho_f)$, where ρ =Density matrix. (iii) State the difference between pure and mixed states. (4+3+1)

b) (i) Calculate the volume of an N-dimensional sphere. (ii) What is the Negative Temperature of a system? Cite example. (iii) Cite the difference between an Ergodic and Non-ergodic system. (4+3+1)

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