PRABHAT KUMAR COLLEGE, CONTAI

M. Sc. 3rd Semester Examination-2021

Subject: Physics Paper: **PHS 301** Full Marks: 50 Time: 2 hr

301.1: Quantum Mechanics-III

Answer any TWO questions

1.a) Justify- "A plane wave can in principle be decomposed into infinite number of partial waves". b) Explain first Born approximation in brief for potential scattering. c) Let σ and $\frac{d\sigma(\theta)}{d\Omega}$ be the total and differential cross-section respectively for scattering of a particle from a real spherically symmetric potential. Then show that $\sigma \leq \frac{4\pi}{K}\sqrt{\frac{d\sigma(\theta)}{d\Omega}}$. d) Also verify this inequality explicitly for a general central potential using the partial wave expansion of the scattering amplitude and the cross section. 2+2+3+3

2. a) Explain the principle of indistinguishability of identical particles. Hence discuss the physical consequence of the phenomenon. b) Consider a hydrogen atom in its ground state is subjected to a spatially uniform time dependent electric field $\varepsilon_0 e^{-t/\tau}$ beyond. Hence probability in the first excited state (n=2, l=1, m). c) Obtain the zeroth-order wave function for the state 1s22s of Lithium atom. 3+5+2

3.a) What is phase shift in case of potential scattering? Explain the nature of phase shift in the case of attractive and repulsive potentials. b) What do you mean by the central field approximation? Discuss the corrections necessary over the central field approximation? c) Assume that (z-1) electrons around nucleus with charge z_e have a charge density $\rho(r) = -\frac{(z-1)e}{4\pi a^3}\frac{e^{-r/a}}{r/a}$. Show that an electron moving in this electrostatic field has a potential energy

$V(r) = -\frac{\chi(r)e^2}{4\pi\varepsilon_0 r}$ where $\chi(r) = (z-1)e^{-\frac{r}{a}} + 1$. 3+3+4

4. a) Write down the Thomas-Fermi equation for many electron systems and hence discuss the validity of this equation. b) Justify that the Greens function acts as a propagator for potential scattering. c) A linear harmonic oscillator of mass m, frequency ω_0 and charge e in excited by an non-resonant field $\vec{A}(\boldsymbol{r},t) = 2A_0\hat{z}\cos(\mathrm{ky}-\omega\mathrm{t})$ for t > 0. Let $|n>$ and $E_n = \hbar\omega(n+1/2)$ be the eigen state and eigen value of the oscillator. Apply first order perturbation theory to find the time dependent state vector $|\psi(t)>$. If $|\psi(t=0) = |0>$. Calculate the induced dipole moment. 3+2+5

Internal Assesment-05

Please turn over

301.2: Statistical Mechanics-I

Answer any TWO questions

1. Evaluate the density matrix ρ_{mn} of an electron spin in the representation that makes $\hat{\sigma}_x$ diagonal. Calculate $\langle \sigma_z \rangle$, resulting from this representation. 5+5

2. Under what condition Fermi-Dirac and Bose-Einstein distributions reduce to Maxwell-Boltzmann distribution. For a canonical ensemble derive the expression for energy fluctuations and explain briefly its significance. 3+7

3. a) A statistical system is composed of N particles with spin 1/2, immersed in a magnetic field H. The particles are fixed in their positions and possess a magnetic moment μ. Write down the Hamiltonian of the system. Determine the entropy, the energy, the specific heat, and the magnetization.
   b) What is Gibb's paradox? 8+2

4. A physical system is composed of N distinguishable spins assuming two possible values ±1. These two values correspond to the energy levels ±ε, respectively. Compute the total energy E using the Boltzmann formula and the microcanonical ensemble. Finally, compare the results with those in the canonical ensemble. 5+5

Internal Assesment-05