MBZ-003-020201-50-4

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Seat No. ______

M. Sc. (Sem. II) (CBCS) Examination

April / May - 2018

Physics : CT-5

(Quantum Mechanics & Statistical Mechanics)

(Old Course)

Faculty Code : 003

Subject Code : 020201

Time : $2\frac{1}{2}$ Hours] [Total Marks : **70**

Instructions : (1) Attempt all questions.

(2) All questions carry equal marks.

(3) Assigned marks are given in brackets on R.H.S.

(4) Mathematical symbols have usual meanings.

1 Answer in brief any **seven** :

(a) What is Scattering Phenomenon ? Explain in brief. **2**

(b) Convert Schrödinger equation into the following form : **2**

$$\left(\nabla^2 + k^2\right)u(x) = U(x)u(x), \text{ where } k^2 = \frac{2mE}{\hbar^2} \text{ and}$$

$$U = \frac{2mV}{\hbar^2}.$$

(c) Write the formula for screened Coulomb potential ? Why this potential is known as "Screened Coulomb" ? **2**

(d) What is the importance of optical theorem in explaining scattering ? Explain in brief without derivation. **2**

(e) Define the energy surface of energy E in the phase space. **2**

(f) Define the partition function and write its mathematical expression. **2**

(g) If the chemical potential in grand canonical ensemble is shown by $\mu = \frac{\partial N a(v)}{\partial N}$ then prove that $\frac{\partial \mu}{\partial v} = -v \frac{\partial^2 a(v)}{\partial v^2}$, where $v = \frac{V}{N}$ **2**

(h) Write postulates of quantum statistics. **2**

(i) Explain the mechanocaloric effect in superfluid. **2**

(j) In the Ising model the energy is given by **2**

$$E_I \{S_i\} = -\in \sum_{\langle i_j \rangle} S_i S_j - H \sum_{i=1}^{N} S_i$$

The corresponds to ferromagnetism in which condition of $\in$? Here H represents what ?

2 Answer any **two** in detail :

(a) What is Born approximation ? Obtain the following expression. **7**

$$f_B(\theta) = -\frac{1}{k} \int_0^\infty U(r) r \sin kr \, dr$$

(b) What is eikonel approximation ? Derive the criterion for the validity of the Born approximation in the following form through the derivation of eikonel approximation : **7**

$$\left| \frac{1}{\hbar v} \int_{-\infty}^{z} V(x, y, z') \, dz' \right| << 1$$

(c) Prove that the differential scattering cross-section is **7**

$$\left(\frac{d\sigma}{d\Omega}\right)_B = \left(|f_B(\theta)|^2\right) = \frac{4\mu^2 V_0^2}{\hbar^4 q^6} \left|(\sin qa - q\, a \cos qa)^2\right| \quad \text{for}$$

the potential well $V(r) = -V_0$ for $r < a$ and $V(r) = 0$ for $r > a$.

3 (a) In the partial wave analysis, derive the following expression for differential scattering cross-section **7**

$$\frac{d\sigma}{d\Omega} = -\frac{1}{K^2}\left[\sin^2\delta_0 + 6\cos\left(\delta_0 - \delta_1\right)\sin\delta_1\sin\delta_0\cos\theta + 9\sin^2\delta_1 + \cos^2\theta\right]$$

Explain the significance of each term.

(b) In the partial wave analysis to express the phase shift in terms of potential, one expresses χ_e with the corresponding function $\chi_e^{(0)} \propto rj_e^{(kr)}$ of the potential free case, using the radial equation **7**

$$\frac{d^2\chi_e}{dr^2} + \left[k^2 - U - \frac{\ell(\ell+1)}{r^2}\right]\chi_e = 0$$

obtain the Born approximation for phase shift.

$$\sin\delta_\ell = -K\int_0^\infty U(r)\,r^2 J_\ell^2(kr)\,dr$$

Here it is considered that χ_e differs very little from $\chi_e^{(0)}$.

OR

3 (a) For the classical ideal gas obtain the following expression for entropy : **7**

$$S = NK\log\left[V\left(\frac{4\pi mE}{3h^2N}\right)^{3/2}\right] + \frac{3}{2}NK$$

(b) What is Gibbs paradox ? Discuss in detail. **7**

4 Answer any **two** in detail :

(a) The energy fluctuations in the canonical ensemble is considered, by using the partition function approach derive the following expression : **7**

$$\frac{1}{N!h^{3N}}\int dpdqe^{-\beta\Im\phi(p,q)} \approx e^{\beta(TS-U)}\sqrt{2\pi\, k\, T^2 C_v}$$

(b) In the grand canonical ensemble, derive the following expression **7**

$$\frac{Q_{N_2}(V,T)}{Q_N(V,T)} = \exp\left\{-\beta\left[A\left(N-N_1, V-V_1, T\right) - A\left(N, V, T\right)\right]\right.$$

(c) Discuss canonical ensemble in quantum statistics. **7**

5 Write notes in detail on any **two** :

(a) Binary alloy and Ising model. **7**

(b) Difficulty in solidification of Helium. **7**

(c) Use of Green's function in scattering theory. **7**

(d) Born series. **7**