2017

M.Sc. 3rd Semester Examination

PHYSICS

PAPER—PHS-301

Full Marks : 40

Time : 2 Hours

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

Illustrate the answers wherever necessary.

Use separate Answer-scripts for Group-A & Group-B

Group-A

[Marks : 20]

Answer Q. No. *1* & *2* and any *one* from the rest.

1. Answer any *three* bits : 2×3

(a) Distinguish between adiabatic and sudden approximation.

(b) What are the suitable conditions for the study of scattering problems by the method of partial waves ?

(c) Explain Laporte selection rule.

(Turn Over)

(d) In context of the He atom plot probability density for Fermi hole and Fermi heap.

(e) 3 non-interacting bosons are trapped in an infinite potential well. Find the ground state energy.

2. Answer any *one* bit : 4

(a) If $\hat{H} = -\gamma \vec{S}.\vec{B}$ where

$\vec{B} = B_0 \hat{z} + \hat{x} B_1 \cos wt - \hat{y} B_1 \sin wt$ is applied on an electron.

Derive the time dependent equation of motion for two level state.

(b) At what neutron lab energy will p-wave be important in n-p scattering ?

3. (a) In case of scattering from a spherically symmetric charge distribution the form factor is given by

$$F(q^2) = \int_0^\infty \rho(r) \frac{\sin\left(\frac{qr}{\hbar}\right)}{\left(\frac{qr}{\hbar}\right)} 4\pi r^2 dr$$

where $\rho(r)$ is the normalized charge distribution.

(i) If the charge distribution of proton is approximately $\rho(r) = Ae^{-r/a}$, where A is a constant and 'a' is some characteristic radius of the proton. Show that form factor is proportional to $\left(1+\frac{q^2}{q_0^2}\right)^{-2}$ where q_0 is $\frac{\hbar}{a}$.

(ii) If $q_0^2 = 0.71\left(\frac{\text{Gev}}{e}\right)^2$, find the characteristic radius of the proton.

(b) Suppose one particle is a state $\psi_a(x)$ and the other is in $\psi_b(x)$. These two states are orthogonal and normalized. If the two particles are distinguishable, the combined wave function is $\psi_d(x_1, x_2)$. Calculate $\left\langle (x_1 - x_2)^2 \right\rangle_d$ for distinguishable particles and identical bosons.

4+3+3

4. (a) A one dimensional infinite potential well of width 'a' contains two spinless particles, each of mass m. The potential representing the interaction between the particles V = A $\delta(x_1 - x_2)$. Calculate the ground state energy of the system of the first order in A.

(b) Obtain the zeroth-order wave function for the atom in the excited state IS2p.

5+5

Group-B

[Marks : 20]

Answer Q. No. *1* and any *one* from the rest.

1. Answer any *five* bits : 2×5

(a) An ensemble of N three level systems with energies $\varepsilon = -\varepsilon_0, 0, +\varepsilon$ is in thermal equilibrium at temperature T. Find the free energy of the system at high temperature.

(b) A system of N particles is enclosed in a volume V at a temperature T. The logarithmic of the partition function is given by $\ln Z = N \ln \left[(V - bN)(k_B T)^{3/2}\right]$ where b is a constant. Find the internal energy of the gas.

(c) The equation of state of a real gas at moderate pressure is $P(V - b) = RT$; where R and b are constants. Find the partition function of the system.

(d) Calculate the chemical potential of a system of N quantum harmonia oscillator having frequency w at temperature T.

(e) Plot the temperature variation of chemical potential of B.E and F.D system of particles.

(f) Prove that magnetic susceptibility of a system obeying classical mechanics and classical statistics is strictly equal to zero.

(g) A two dimensional vector $\vec{A}$ of given length $A = |\vec{A}|$ is equally likely to point in any direction specified by the angle θ from the x-axis. Find $\langle A_x \rangle$.

2. (a) In a uniform magnetic field B taken along z direction, the energy level of an electron is given by

$$E(l,\ p_z) = \hbar w_c\left(l + \tfrac{1}{2}\right) + \frac{p_z^2}{2m}$$

where $l = 0, 1, 2, \ldots. \infty$ and $w_c = \dfrac{eB}{mc}$.

(i) Find the degeneracy of the energy level.

(ii) Calculate the partition function of the system.

(iii) Show the magnetization at high temperature

$$M = -\mu_B \lambda\left(\frac{\mu_B B}{k_B T}\right).$$

where λ is the Langevin function.

(b) Show that energy fluctuation in a canonical distribution is given by

$$\left\langle \left(E - \overline{E}\right)^2 \right\rangle = k_B T^2 C_v .$$

2+3+2+3

3. (a) Prove that pure state remains pure always.

(b) Calculate the average value of q^2 for a quantum oscillator as function of T.

$$\hat{H} = -\frac{\hbar^2}{2m}\frac{d^2}{dq^2} + \frac{1}{2}mw^2\hat{q}^2$$

Determine and explain the limiting values of $\langle q^2 \rangle$ for

$\frac{k_B T}{\hbar w} \gg 1$ and $\frac{k_B T}{\hbar w} \ll 1$.

Given : $\langle q | e^{-\beta \hat{H}} | q' \rangle = \left[\frac{mw}{2\pi\hbar \sinh(\beta\hbar w)} \right]^{1/2} \times$

$$\exp\left[\frac{-mw}{4\hbar} \left\{ (q+q')^2 \tanh\left(\frac{\beta\hbar w}{2}\right) + (q-q')^2 \coth\left(\frac{\beta\hbar w}{2}\right) \right\} \right].$$

2+4+4

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