M.Sc.

2009

4th Semester Examination

PHYSICS

PAPER—PH-2201

Full Marks : 40

Time : 2 Hours

The figures in the right-hand margin indicate full marks.

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

Illustrate the answers wherever necessary.

Group—A

(*Marks : 20*)

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

1. Answer any *five* bits : 2×5

(a) Show that if a wave function is an eigenstate of a symmetric Hamiltorian, corresponding to a non-degenerate eigenvalue, then it is either symmetric or antisymmetric.

(b) For a two electron atom express the form of coulomb energy and exchange energy. Give the energy of the singlet and triplet state to first order in there energies.

(c) Define differential scattering cross-section and show that it is equal to the absolute square of scattering amplitude.

(d) Two non-interacting electrons are confined to an infinite potential well

$$v(x) = \begin{cases} 0 & 0 < x < a \\ \infty & 0 > x > a \end{cases}$$

find the energy and wave function in the first excited state.

(e) Find the expression for phase shift 'δ' of the scattered particle from a central potential v(r) using Born approximation. Show that the particles gain phase when the scattering potential is attractive and loose in phase for repulsive potential.

(f) Show with a diagram the splitting of energy levels of $2p_{3/2}$, $2p_{1/2}$ and $2s_{1/2}$ levels due to application of a weak magnetic field.

(g) Give the zeroth order wave function for Helium atom (i) in the ground state $1s^2$ and (ii) in the excited state 1s2s.

(h) A system consists of three identical indistinguishable particles. Construct symmetric and antisymmetric wave functions from unsymmetrised wave functions.

2. (i) In an excited state of alkali atom doublet structure show that $2p_{3/2}$ state has higher energy than $2p_{1/2}$ state.

(ii) Draw the energy level diagram for the $2p_{3/2}$, $2p_{1/2}$ and $2s_{1/2}$ states and write the wave functions in terms of the spherical harmonics $Y_{lm}(\theta, \phi)$ and the spin states $|\uparrow\rangle$ or $|\downarrow\rangle$. Show all the possible electric dipole allowed transitions.

(iii) Find the square of the dipole matrix elements for ex, ey and ez between the states

$|2p_{3/2}\ m = 3/2\rangle$ to $\langle 2s_{1/2}\ m = 1/2|$.

Given $Y_{11} = -\sqrt{\frac{3}{8\pi}} \sin\theta e^{i\phi}$

$$Y_{00} = \frac{1}{\sqrt{4\pi}}$$

Also comment on the intensities of the lines $2p_{3/2} - 2s_{1/2}$ and $2p_{1/2} - 2s_{1/2}$. 2+4+4

3. (a) Starting from the general solution of the Schrodinger equation for a free particle :

$$\psi(r,\theta,\phi) = \sum_{l=0}^{\infty}\left[A_l j_l(Kr) + B_l n_l(Kr)\right] Y_{lm}(\theta,\phi)$$

Show that the plane wave e^{ikz} representing free particle beam moving along z-axis can be expressed as

$$e^{ikz} = \sum_{l=0}^{\infty} i^l(2l+1)\ j_l(Kr)\ P_l(\cos\theta)$$

(b) Consider scattering of a particle beam moving along z axis by a spherically symmetric potential centred at origin.

Assuming asymptotic solution show that scattering amplitude is given by

$$f(\theta) = \frac{1}{K}\sum_{l=0}^{\infty}(2l+1)\, e^{i\delta_l}\ P_l(\cos\theta)\sin\delta_l.$$

(The symbols have their usual meaning.) 5+5

Group—B

(Marks : 20)

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

1. Answer any *five* from the following : 2×5

(a) Write down the expression for free energy of F.D. gas under magnetic quantization.

(b) Define 2nd order phase transition in terms of order parameter.

(c) Write down an expression for Isothermal susceptibility according to G–L theory of phase transition.

(d) Explain phase transition in the light of Lee and Yang's Theory.

(e) How Bragg William approximation predicts MFA?

(f) In what limit do the B–E and F–D gas behave as classical gases and why?

(g) Draw graphically P *vs.* T plot for chemical, B–E and F–D gases.

(h) Distinguish between He–I and He–II in the light of two fluid model.

2. (a) Show that for a two-dimensional ideal B–E gas, number of particles

$$N = \frac{A2\pi m k_B T}{h^2} B_1(\alpha),$$

where $\alpha = -\mu\beta$; $\beta = \frac{1}{k_B T}$; A is the area. Other symbols have usual meanings. Can it undergo B–E condensation? 4+1

(b) Prove that in a photoelectric effect, current density

$$j = \frac{2\pi ame}{h}(\nu - \nu_0)^2,$$

where a = probability of absorption of photon in a metal ; ν_0 = threshold frequency.

(Assume $(h\nu - h\nu_0) >> k_BT$.) Other notations bear their usual meanings. 5

3. (a) Find out the behaviour of the specific heat of fermions at very low temperatures using qualitative arguments. Compare the behaviour of specific heat as a function of temperature for a Bose gas and a Fermi gas by a schematic picture. 2+2

(b) Find out the expression of the free energy of non-interacting electrons in a magnetic field. In what respect is the behaviour of this system different from a paramagnetic material and why? 4+2

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