M.Sc. 1st Semester Examination, 2012

PHYSICS

PAPER – PHS- 102(A + B)

Full Marks : 40

Time : 2 hours

The figures in the right hand margin indicate 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* questions : 2 × 5

(*a*) Wavelengths can be determined with accuracies of one part in 10^4. What is the uncertainty in the position of 1Å X-ray photon when its wavelength is simultaneously measured ?

(*b*) Deduce the parity of the spherical harmonics $Y_{lm}(\theta, \phi)$.

(*c*) The quantum state of a two-level system with energy (in eV) is given as

$$\psi(\vec{r}, t) = 0{\cdot}8\ \psi_1(\vec{r}) + 0{\cdot}6\ e^{it/\hbar}\psi_2(\vec{r}).$$

What are the energy values of two states ? Find the outcome of energy measurement (with probability) on the system.

(*d*) Evaluate $< x >$ and $< p >$ for a particle in a one-dimensional infinitely deep potential well.

(*e*) From the equation $H\psi = E\psi$. Calculate the variance of H, which is given by

$$\sigma^2 = < H^2 > - < H >^2.$$

(*f*) $\{|u_i> i = 1, 2, \ldots\}$ form the basis of a certain vector spare. Show that,

$$\sum_i |u_i><u_i| = 1.$$

[Take $\{|u_i>\}$ to form an orthonormal set.]

(*g*) Prove that the parity operator is Hermitian.

(*h*) The radial equation for an infinite spherical well ($V(r) = 0$ if $r < a$ and $V(r) = \infty$ if $r > a$) is given by

$$\frac{d^2u}{dr^2} = \left[\frac{l(l+1)}{r^2} - k^2\right]u$$

where, $k = \sqrt{2mE}/\hbar$ and $u(r) \equiv r\,R\,(r)$ with symbols having their usual meaning cheek that, for $l = 0$, the allowed energies are the same as in the case of a one dimensional infinite well.

2. (*a*) A particle, trapped in a one-dimensional infinite square well ($0 \le x < L$), is described by the wave function

$$\psi(x,0) = \frac{1}{\sqrt{L}} \sin\frac{5\pi x}{L} \cos\frac{2\pi x}{L}.$$

(*i*) Normalise $\psi\,(x, 0)$, (*ii*) Expand $\psi\,(x, 0)$ in terms of energy eigen functions, (*iii*) Find $\psi\,(x, t)$, (*iv*) Is $\psi(x, t)$ a stationary state. ?

(*b*) Prove that the eigenstates of a Hermitian operator belonging to different eigenvalues are mutually orthogonal.

(*c*) Prove that, if two operators have simultaneous eigenstates, then they commute consider the non-degenerate case only. $(2 + 2 + 1 + 1) + 2 + 2$

3. (*a*) Write the Schrödinger equation for a Hydrogen atom.

(*b*) Write the equation in the centre of mass and relative coordinates separately.

(*c*) Write the radial equation in the relative co-ordinate system.

(*d*) Find the energy eigenvalues for the Hydrogen atom and discuss the degeneracy of the levels.

$1 + 1 + 1 + (6 + 1)$

GROUP – B

[*Marks* : 20]

Answer **Q.Nos.1** & **2** and any **one** from the rest

1. Answer any *two* bits : 2×2

(*a*) Show that five fold rotational axis does not exist in a lattice system.

(*b*) Show that density of states becomes infinity at the zone boundary for a linear monatomic lattice.

(*c*) Lead in the superconducting state has critical temperature of 6·2 K at zero magnetic field and a critical field of 0·064 Am^{-1} at OK. Determine the critical field at 4K.

2. Answer any *two* : 3×2

(*a*) Show by matrix representation that $2/m \equiv i$, two fold rotation is about z-axis and mirror plane is perpendicular to the z-axis.

(*b*) Show that brillouin zone of 'bcc' lattice is rhombodecahedrah.

(*c*) Sound velocity in solids are of the order of $3 \times 10^3\ ms^{-1}$. Interatomic distance in solids is 3×10^{-10} m. Calculate the value of cut off frequency.

3. (*a*) Explain Debye-Waller effect and find an expression of Debye-Waller factor.

(*b*) What is geometrical structure factor? Show that the factor vanishes unless the number h, k and l are all even or all odd for fcc lattice.

$(2 + 4) + 4$

4. (*a*) Describe the movement of atoms in the optical and acoustical modes of wave propagation for a linear diatomic crystal.

(*b*) Apply thermodynamics to find the expressions of (*i*) $G_n - G_s$ and (*ii*) $S_n - S_s$,

where $dG = -SdT - MdB$

G = Gibbs free energy per unit volume,

S = entropy per unit volume,

B = Magnetic induction and

M = Magnetisation.

The subscripts n and s refer to normal and superconducting states. 6 + (2 + 2)