PG/IS/PHY/PH-1102/09

M.Sc 1st Semester Examination, 2009

PHYSICS

(*Quantum Mechanics* - I)

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

PAPER—PH- 1102 (A)

[*Marks* : 20]

Time : 1 hour

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

1. Answer any *five* bits : 2×5

(*a*) Estimate the kinetic energy of neutrons needed for the study of neutron diffraction of crystal structures, if the interatomic spacing in the crystal is of the order of 2 Å.

(*Turn Over*)

(*b*) Prove that the eigenfunctions corresponding to different eigenvalues of a Hermitian Operator are orthogonal.

(*c*) The wavefunction of a particle in a state is $\Psi(x) = Ae^{-ax^2}$. Find the value Δx.

(*d*) An electron is confined to an one dimensional rigid box of length 5 Å. (*i*) calculate the three lowest energy eigenvalues (*ii*) find the frequency of radiation when it undergoes transition from first excited state to ground state.

(*e*) A system in a state $|\psi\rangle$ is given by $|\psi\rangle = \sqrt{3}\,|\psi_1\rangle + |\psi_2\rangle$ where $|\psi_1\rangle$ and $|\psi_2\rangle$ are eigenfunctions of the Hamiltonian operator with energies ε_1 and ε_2 respectively. Find the expectation value of energy for the given state.

(*f*) The ground state wavefunction of a particle of mass m is given by $\psi(x) = e^{-\alpha^2 x^2/4}$ with energy eigenvalue $\frac{\hbar^2 \alpha^2}{4}$. What is the potential in which the particle moves?

(*g*) The form of the wavefunction for the hydrogen atom is given as

$$\psi_{nlm} = \left(\frac{z}{a_0}\right)^{3/2} \frac{2}{81\sqrt{x}} \left(\frac{zr}{a_0}\right)^2 e^{-\frac{zr}{3a_0}} \sin\theta \cos\theta \, e^{i\phi}.$$

Find l, m and parity.

(*h*) Write the form of L_z in spherical polar co-ordinates. Find the eigenvalues and normalised eigenfunctions for this operator L_z.

2. (*a*) Evaluate the transmission coefficient for an electron of energy 4 eV incident upon a rectangular potential barrier of height 6 eV and thickness 2 nm.

(*b*) Write the Hamiltonian for a one dimensional harmonic oscillator. Write its energy eigenvalues.

(*c*) Write and draw the wavefunction of the harmonic oscillator in the two lowest states.

(*d*) Determine the probability of finding the oscillator in the ground state inside the classical limit.

(*e*) Find the zeroth order energy of the oscillator using Heisenberg Uncertainty principle.

3 + 1 + 2 + 2 + 2

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

(*b*) Write the two equations corresponding to centre of mass and relative co-ordinates.

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

(*d*) Solve the radial equation to obtain the energy eigenvalues.

(*e*) Discuss the degeneracy's associated with the energy levels. If the coulomb potential is replaced by some other spherically symmetric potential, which degeneracy will be lifted?

1 + 1 + 1 + 5 + 2

PAPER—PH-1102 (B)

[*Marks* : 20]

Time : 1 hour

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

1. Answer any *two* bits : 2 x 2

(*a*) Show that a face centred tetragonal lattice can be replaced by a body centred tetragonal lattice.

(*b*) Find the Brillouin Zone of f.c.c lattice.

(*c*) What is Meissner Effect ?

2. Answer any *two* bits : 3 x 2

(*a*) Define space group and point group with examples.

(*b*) If the velocity of sound in a solid is taken to be 3×10^3 m/s and the interionic distance as 3×10^{-10} m, calculate the value of cut-off frequency assuming a linear lattice.

(*c*) Obtain an expression for the London penetration depth in a superconducting specimen.

3. (*a*) Derive Bragg's diffraction condition in terms of reciprocal lattice vector and also define Brillouin zone. 2 + 1

(*b*) Find an expression for structure factor in term of fractional co-ordinate. Apply it in case of a face centred cubic crystal and find out the condition for systematic absence. $2\frac{1}{2} + 2\frac{1}{2}$

(*c*) Calculate the energy in eV corresponding to a wavelength of 1 Å for X-rays and electron. 1 + 1

4. (*a*) Explain why silver metal obeys Dulong–Petit law at room temperature but the diamond does not. Explain it assuming Einstien frequency for Ag $= 4 \times 10^{12}$ cycles/second and for diamond $= 2{\cdot}4 \times 10^{13}$ cycles/second. 2

(*b*) Prove the equibalence between a vibrational mode and a Simple Harmonic Oscillator. 6

(*c*) Show that five fold rotational axis does not exist in a lattice system. 2

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