M.Sc. 1st Semester Examination, 2019

PHYSICS

PAPER – PHS-102

Full Marks : 40

Time : 2 hours

Answer **all** questions

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

Write the answers to questions of each Unit in separate books

UNIT– PHY-102.1

(*Quantum Mechanics*-I)

1. Answer any *two* questions: 2 × 2

(*a*) A square wave packet

$$\psi(x) = Ae^{ik_0 x} \quad \text{for } |x| \leq a$$
$$= 0 \qquad \text{for } |x| > a$$

Find $\phi(k)$. (momentum wave function).

(*b*) A particle of mass m is subjected to a potential

$$V(x, y) = \frac{1}{2} mw^2 (x^2 + y^2) :$$

$$-\infty \leq x \leq +\infty ; \; -\infty \leq y \leq +\infty$$

The state with energy $4\hbar w$ is g-fold degenerate. Find the value of g.

(*c*) Show that $e^{i\hat{p}a/\hbar} \hat{x} e^{-i\hat{p}a/\hbar} = \hat{x} + \hat{a}$.

(*d*) What operator may be used to distinguish between

(*i*) e^{ikx} and e^{-ikx} (*ii*) sin ax and cos ax ?

2. Answer any *two* questions : 4×2

(*a*) An electron in the ground state of the hydrogen atom has the wave function

$$\psi(r) = \frac{1}{\sqrt{\pi a_0^3}} \; e^{-r/a_0}$$

whare a_0 is constant. Find the expectation value of the operator $\hat{Q} = z^2 - r^2$.

(*b*) Let $|0\rangle$ and $|1\rangle$ denote normalized eigenstates corresponding to the ground and first state of a 1-*D* harmonic oscillator. Find the uncertainty Δp in the state $\frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$.

(*c*) A particle of mass *m* in the one-dimensional short range potential $V(x) = -V_0 \delta(x)$: $V_0 \rangle 0$. Find the energy of the system.

(*d*) A particle is confined to the region $x \geq 0$ by a potential which increases as $V(x) = V_0 x$. Find $\langle x \rangle$ as a function of temperature *T*.

3. Answer any *one* question : 8×1

(*a*) For a harmonic oscillator, the Hamiltonian in dimensionless units is

$$\hat{H} = aa^{+} - \frac{1}{2}$$

The energy eigenfunction of a state is

$$\psi_n = (2x^3 - 3x)\exp\left(-\frac{x^2}{2}\right).$$

What is its state ? Find the eigenfunctions corresponding to the adjacent states. $4 + 2 + 2$

(*b*) (*i*) A particle of mass m is confined to the interior of a hollow spherical cavity of radius R_1 with impenetrable walls. Find the pressure exerted on the walls of the cavity by the particle in its ground state.

(*ii*) For He^{+}, $R_{10}(r) = 2\left(\frac{Z}{a_0}\right)^{3/2} e^{-\frac{zr}{a_0}}$

show that $\left\langle \frac{1}{r} \right\rangle = \frac{2}{a_0}$. $5 + 3$

UNIT – PHY-102.2

(*Solid State*-I)

4. Answer any *two* questions : 2 × 2

(*a*) Show that face centered tetragonal lattice can be converted to base centered tetragonal lattice ?

(*b*) Show geometrically that reciprocal lattice is a projection of direct lattice ?

(*c*) What is meant by Stationary Boundary condition and hence find the possible modes for one dimensional linear chain of atoms.

(*d*) What is meant by effective mass of an electron in a solid ? What does negative effective mass correspond to ?

5. Answer any *two* questions : 4 × 2

(*a*) Explain Glide and Screw symmetry elements in a periodic lattice. Why are they called internal symmetry elements ?

(*b*) Find an expression of density of states for a linear chain of atoms. What is van Houe Singularity ?

(*c*) Find an expression of structure factor interms of fractional coordinates ? How can you identify the presence of 2_1 screw using structure factor ?

(*d*) The Conduction band and Valence band structure of a solid is given by

$E_{cb} = E_1 - E_2 \cos ka$ and $E_{vb} = E_2 - E_3$.

Find the nature of the band gap, value of band gap. Also find $m*$ at the bottom of conduction band.

6. Answer any *one* bit : 8 × 1

(*a*) Derive the dispersion relation of one dimensional diatomic lattice and hence clearly distinguish the characteristics of two branches. 6 + 2

(*b*) Derive an expression of Scattered intensity considering the scattering of X-rays from a crystal. 8
