2017

M.Sc.

1st Semester Examination

PHYSICS

PAPER—PHS-102

Subject Code—33

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.

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

(Quantum Mechanics–I)

Group—A

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

1. Answer any *five* bits : 5×2

(a) If $E^2 = p^2c^2 + m^2c^4$, then prove that $v_p v_g = c^2$ where v_p and v_g are phase and group velocity respectively.

(b) Show that $\left(\frac{d}{dx}\right)^{\dagger} = -\frac{d}{dx}$.

(c) If $\hat{A} = \alpha\hat{x} + i\beta\hat{p}$; α, β are real number. Find $[\hat{A}, \hat{x}]$ and $[\hat{A}, \hat{p}]$

(d) A real operator $\hat{A}$ satisfies the lowest order equation $\hat{A}^2 - 4\hat{A} + 3 = 0$ show that $\hat{A}$ is an observable.

(e) For a system of fermions, the creation operator (a_k^+) and annihilation operator (a_k) obey $\{a_k, a_k^+\} = \delta_{kl}$. Show that the eigen values of the number operator N_k defined by $n_k = a_k^+ a_k$ are 0 and 1.

(f) Write down the expression of probability current density for a charge particle in terms of vector potential $\vec{A}$.

(g) A particle of mass m moves in a spherically symmetric potential $V = kr$, where k is a positive constant. Find the ground state energy.

(h) Show that, if the Hamiltonian H of a system does not depend explicity on time. The ket $|\psi(t)\rangle$ varies with time according to

$$|\psi(t)\rangle = \exp\left(-\frac{iHt}{\hbar}\right)|\psi(0)\rangle$$

2. (a) Taking the gr. state eigen function $\psi(r) = \frac{1}{\sqrt{\pi a_0^3}} e^{-r/a}$. Show that for an electron in the ground state of the hydrogen atom the momentum-probability distribution is given by

$$\frac{8}{\pi^2} \frac{(\hbar / a_0)^5}{\left[p^2 + \left(\frac{\hbar}{a_0}\right)^2\right]^4}$$

(b) Show that (i) the most probable magnitude of the momentum of the electron is $\frac{\hbar}{\sqrt{3}a_0}$. (ii) its mean value is $\frac{8\hbar}{3\pi a_0}$, where a_0 is the Bhor radius.

3. (a) At t = 0, particle in a harmonic oscillator potential $\psi(x,0) = \frac{1}{\sqrt{2}}[\psi_0(x) + \psi_1(x)]$. Where $\psi_1(x)$ are real orthonormal eigen functions for the ground and first excited states of the oscillator. Show that probability density $|\psi(x,t)|^2$ oscillates with angular frequency w.

(b) Find the number of bound states for a particle of mass 2200 electron mass in a square well potential of depth 70 Mev and radius 1.42 fm.

(c) A particle of mass m is trapped in a hollow sphere of radius R with impenetrable walls. Obtain an expression for the force exerted on the walls of the sphere by the particle in the ground state. 5+2+3

Group—B

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

1. Answer any *two* bits : 2×2

(a) Show that five fold rotational symmetry is absent in Bravis lattice.

(b) Explain what is meant by Miller-Bravis indices ?

(c) Show the stereogram and matrix representation for point group 222.

2. Answer any *two* bits : 2×3

(a) Find the structure factor of diamond and find the condition of allowed reflection. 3

(b) Clearly explain what is meant by single crystal and polycrystalline material. How they can be distinguihed experimentally ? 1½+1½

(c) Find an expression of effective mass in a solid ? What is meant by negative effective mass ? 2+1

3. (a) Derive Laue equation assuming x-ray falling on a crystal.

(b) What is a Brillonin zone ? 8+2

4. (a) Derive density of states for one dimensional monatomic chain of vilerating atoms. What is Van Hove singularity ?

(b) Explain what is the physical origin of energy gap in a solid ?

(c) What is optical branch and why it is so called.

4+1+3½+1½
