RAMAKRISHNA MISSION VIDYAMANDIRA

(Residential Autonomous College under University of Calcutta)

B.A./B.SC. FIFTH SEMESTER EXAMINATION, DECEMBER 2013

THIRD YEAR

Date : 19/12/2013 **PHYSICS (Honours)**

Time : 11 am – 1 pm Paper : V Full Marks : 50

Group – B

Sec – I

(*Answer **any three** of the following*)

1. a) Deduce an expression for the frequency shift due to Compton scattering. Justify the existence of the unmodified line spectrum. [5+2]

   b) A particle of mass m is confined in a one-dimensional box of length L. Estimate from the uncertainty principle the minimum energy of the particle if it moves freely inside the box. [3]

2. a) Find out the de Broglie wavelength of an electron of total energy 2MeV. [4]

   b) Starting from the time dependent Schroedinger equation, deduce the equation of conservation of probability explaining the assumptions you make. Can the normalization constant be uniquely determined? [5+1]

3. a) A particle is moving in a one-dimensional potential well defined by
   $V(x) = 0$ for $-a<x<a$
   $= -v_0$ elsewhere
   Obtain the energy eigenvalue equation. [5]

   b) A particle is in a state given by $\psi = c_1\psi_1 + c_2\psi_2$ where ψ_1 and ψ_2 represent eigenstates with energy values equal to E_1 and E_2 respectively. If the average energy in the state is E_0, then calculate c_1 and c_2. ψ, ψ_1 and ψ_2 are normalized. [5]

4. a) Deduce Ehrenfest equation $\frac{\partial}{\partial t} < \vec{p} >= -\vec{\nabla}V$. [3]

   b) Consider a beam of electrons travelling to the right along the x-axis with energy E. The potential energy is V = 0 for x < 0, but at x = 0, there is a potential step, and the potential energy increases to (positive) V_0 for x > 0. Assuming that $E > V_0$ calculate the reflection and transmission co-efficients. [7]

5. a) Consider the pulselike wave function $\psi(x) = A\exp\left(-\frac{x^2}{2a^2}\right)$, where a is a constant with the dimensions of length. What value of A is needed to normalize this wave function? [3]

   b) Calculate <p> for the normalized wave function obtained in (5a). You can give physical arguments to estimate the expectation value. [4]

   c) Calculate the zero point energy of a particle of mass 10gm oscillating simple harmonically along the x-axis under a force of restitution of 10^7 dynes/cm. [3]

6. a) Evaluate the following commutator brackets : $[x, L_x]$, $[x, L_y]$ and $[p_x, L_x]$
   The symbols have their usual meaning. [3]

   b) The radial part of the round state wave function of the Hydrogen atom is given by $R_{gs} = \left(\frac{1}{\pi a_0^3}\right)^{\frac{1}{2}} \exp\left(-\frac{r}{a_0}\right)$, where the symbols have their usual meaning. Calculate—

   i) the expectation value of the electron radius in the ground state, and

   ii) the most probable value of the electron radius in the ground state. [4+3]

Sec – II

(*Answer **any two** of the following*)

7. a) What is Larmor precession in atomic spectra? How do we get the idea of space quantizaion from this precession? Illustrate the orientations of the orbits if $\ell = 2$? Also calculate the angles between angular momentum and magnetic field vectors. [1+4+1+2]

   b) Classical rotational frequency of electron in the Bohr orbit is 10^{14} Hz. Calculate the magnetic field inside the H-atom. [2]

8. a) Explain theoretically how one can have the concept of spin magnetic moment from Stern-Gerlach experiment. [4]

   b) An HCl molecule can be assumed to be a simple harmonic oscillator where the hydrogen and chlorine atoms are connected by a spring of spring constant 516 N-m^{-1}. What will be the natural frequency of vibration of the molecules of small amplitude? Given atomic masses of H, m_H = 1·0078u and of Cl = 35 m_H where 1u = $1{\cdot}66\times10^{-27}$ kg. [4]

   c) What will be the quantized energy levels of the molecule for vibrational states? Is the expression for energy levels valid for large quantum numbers? Comment. [2]

9. a) Determine a relation between Einstein's A and B coefficients. [3]

   b) What do you understand by population inversion? Why do you need population inversion in a laser? [1+2]

   c) A laser beam with $\lambda = 632{\cdot}8\,\text{nm}$ is 0·1mm in diameter. If the beam delivers 10^{17} photons per second, what is the power of the laser? What is the radiation pressure this beam can exert? [4]