Jharkhand University of Technology, Ranchi

B.Tech. 2nd Semester Examination, 2019(A)

(Held in May, 19)

Subject : Physics-II (Intro. to Quant. Mech. for Engineers) **Subject Code : BSC-105**

Time Allowed : 3 Hours **Full Marks : 70**

Candidates are required to give their answer in their own words as far as practicable.

The figures in the margin indicate full marks.

Answer any five *questions.*

1. Choose the correct answer: 14

(i) The correct relation is

(a) $v_g = v_p - \lambda \frac{dv_p}{d\lambda}$ (b) $v_p = v_g - \lambda \frac{dv_g}{d\lambda}$

(c) $v_g = v_p + \lambda \frac{dv_p}{d\lambda}$ (d) $v_p = v_g - \frac{1}{\lambda} \frac{dv_p}{d\lambda}$

(ii) The zero point energy of harmonic oscillator is

(a) $\hbar\omega$ (b) $\frac{\hbar\omega}{2}$

(c) $2\,\hbar\omega$ (d) $\frac{\hbar\omega}{4}$

(iii) In the case of a potential step of height V_o. If a particle of energy $E < V_o$ the transmittance is

(a) zero (b) finite non–zero

(c) infinite (d) 1

(iv) The quantity $|\psi|^2$ represent the

(a) probability density (b) charge density

(c) energy density (d) intensity of the wave

(v) According to quantum free electron theory, electrons distributed in various energy levels obey

(a) Pauli's exclusion principle. (b) Sommerfeld principle.

(c) Heisenberg uncertainty principle (d) None of these

(vi) Fermi energy of a material is defined as

(a) energy of highest level occupied by electron at zero kelvin.

(b) energy of free electron in conduction band above zero kelvin.

(c) energy of lowest level occupied by electron at zero kelvin.

(d) Both (a) and (b)

(vii) The operator of the component of the angular momentum along the z-axis is (in the spherical coordinates) $L_z = -i\hbar\frac{\partial}{\partial\varphi}$. The function $f(\theta, \varphi) = C \sin\theta\, e^{i\varphi}$ is an eigen function of this operator. The corresponding eigenvalue m is

(a) 2
(b) −1
(c) 0
(d) 1
(e) 2

Or,

Obtain Schrödinger time dependent wave equation and separate it into space and time dependent parts. Give the probability interpretation of the wave function and show that the probability density ρ and the probability current density J satisfy the continuity equation $\frac{d\rho}{dt} + \nabla . J = 0$. 14

2. (a) What is Compton effect? Give its physical significance. How does it support the photon nature of light?

(b) A beam of particles with energy E is incident on a potential barrier with potential function

$$V(x) = 0 \text{ for } x < 0$$
$$= V_0 \text{ for } 0 < x < a$$
$$= 0 \text{ for } x > a$$

show that there is a finite probability of transmission even if $E < V_0$. 7+7=14

3. (a) Explain the wave particle duality of matter and obtain an expression for the de-Broglie wavelength. Describe Davisson and Germer's experiment. How does it prove the wave nature of particle?

(b) What is meant by wave packet? Differentiate between the phase velocity and the group velocity. Show that the velocity of a moving material particle is equivalent to the velocity of wave packet. 7+7=14

4. (a) Explain the uncertainty principle from the phenomenon of diffraction at a single slit and gamma ray microscope. Use uncertainty principle to prove that electrons cannot exist in the nucleus.

(b) Calculate the minimum energy of the harmonic oscillator by the help of the uncertainty principle. 7+7=14

5. (a) What is an operator? Write the operators associated with energy and linear momentum.

(b) What do you mean by expectation values of dynamical quantities?

(c) Normalise the wave function $\psi = Ae^{\frac{-ax^2}{2}} e^{\frac{iEt}{\hbar}}$ for $x = -\infty$ to $x = +\infty$ and find the expectation values of x and x^2, given that $\int_{-\infty}^{+\infty} e^{-ax^2} dx = \sqrt{\frac{\pi}{a}}$, $\int_{-\infty}^{+\infty} xe^{-ax^2} dx = 0$ and $\int_{-\infty}^{+\infty} x^2 e^{-ax^2} dx = \frac{1}{2}\sqrt{\frac{\pi}{a^3}}$. 3+3+8=14

6. (a) Write the expression of angular momentum operator L^2 in terms of spherical polar coordinates.

   (b) What is rigid rotator? State the expression for its energy level separation. 7+7=14

7. Define density of states of electrons. How does density of states of the free electrons vary with their energy? Give the theory for calculation of Fermi energy at $T = 0$K and average K.E. of an electron at $T \simeq 0$K. 14
