PHD101

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B.Sc. (CBCS) (Semester -V)
EXAMINATION NOVEMBER 2022
Physics
Quantum Mechanics

[Duration : 2 Hours] **[Total Marks :80]**

Instructions:

1) **All** questions are **compulsory.**
2) Figures to the **right** indicate **full** marks.
3) **Symbols** have their usual meaning unless otherwise stated.
4) Draw neat diagrams **wherever** necessary.
5) **Use** of calculator is **permitted.**
6) Given: h=6.62×10^{-34} J-s; e=$1.6 \times 10^{-19} C$; Me=9.1×10^{-31}Kg.

Q.1 Answer any **four** of the following: **[4x4=16]**

a) Illustrate Heisenberg uncertainty principle by Gamma ray thought experiment.
b) State de-Broglie's hypothesis. Using the hypothesis, show that, an electron cannot exist in those orbits whose length is not a whole multiple of h/2π.
c) Explain physical meaning of wave function $\psi(x, y, z, t)$. What is meant by Max Born's interpretation of wave function.
d) What is the meaning of expectation value of a physical quantity? Explain how expectation values of momentum and energy of a particle can be determined using the wave function $\psi(x, t)$ in a one dimensional motion of the particle.
e) Derive the formula expressing De-Broglie's wavelength (in Angstrom units) of an electron in terms of potential difference V (in volts) through which it is accelerated.
f) Explain the significance of zero-point energy of a harmonic oscillator.

Q.2 Answer **any four** of the following: **[4x4=16]**

a) State Heisenberg Uncertainty principle. Show that, for a free particle the uncertainty principle can be written as $\Delta\lambda . \Delta x \geq \frac{\lambda^2}{4\pi}$, where λ is the wavelength of de-Broglie wave associated with the particle.
b) State the conditions that must be satisfied by a well behaved wave function.
c) Deduce operator representation for kinetic energy and momentum of a material particle.
d) What is a wave group description of a matter wave? Show that, the wave group velocity is equal to the particle velocity.

e) The wave function of a particle inside a one dimensional box of length L is

$\psi_n(x) = \sqrt{\frac{2}{L}} Sin(\frac{n\pi x}{L})$ calculate its mean position.

f) Explain the phenomena of ∝-decay as tunneling across a potential barrier.

Q.3 A)

a) Show that the group velocity and phase velocities related by: $Vg = V_P - \lambda \frac{dV_p}{d\lambda}$ [3]

b) Explain in short the G. P. Thomson experiment as a qualitative confirmation of the de Broglie's hypothesis. [3]

OR

x) Explain single slit diffraction experiment in the light of Heisenberg's Uncertainty principle. [3]

y) Calculate the uncertainty in measurement of momentum of an electron if the uncertainty in locating it is $1A^0$ [3]

B) Describe Davisson and Germer experiment. How it does qualitatively and quantitatively confirms de Broglie's hypothesis? [6]

Q.4 A)

a) Show that: [3]

$$\left(\frac{d}{dx} + x\right)\left(\frac{d}{dx} - x\right) = \frac{d^2}{dx^2} - x^2 - 1$$

b) A particle limited to the x-axis has the wave function '$\psi = ax$' between 'x=0' and 'x=1'; '$\psi = 0$' elsewhere. Find probability the expectation value <x> of the particle's position. [3]

OR

x) An Eigen function of the operator $\frac{d^2}{dx^2}$ is $\psi = e^{4x}$Find the corresponding eigen value. [3]

y) A hydrogen atom is 5.3×10^{-11} m. in radius. Estimate the minimum energy an electron can have in this atom. [3]

B) Obtain Schrödinger's time dependent equation using a free particle wave equation. [6]

Q.5 A)

a) Draw diagram showing lowest three wave functions for a particle confined to a one dimensional harmonic oscillator. [3]

b) Explain the phenomena of wave mechanical tunneling of potential barrier using a tunnel diode. [3]

OR

x) Prove the following commutation relation: [3]
$[[A, B], C] + [[B, C), A] + [C, A], B] = 0$

y) Using energy and momentum operators, deduce Schrödinger's time dependent equation for a particle [3]

B) A particle is incident on a step potential V_0, at x=o from the left with energy $E>V_0$. Find the expression for the reflection and transmission coefficients. [6]

Q.6 A)

a) Sketch the Eigen function $\psi(x)$ and corresponding probability densities $\psi(x) * \psi(x)$ for the states n=1, 2 and 3 for a particle in a one dimensional box. [3]

b) Calculate zero point energy of a harmonic oscillator of frequency 2×10^{15} htz. [3]

OR

x) Electron with energy 1.0eV is incident on a barrier10.0 eV high and 0.5 nm wide. Find the transmission probability: [3]

y) Show that for a particle in a three dimensional box single value of energy, different quantum states are possible. Explain the term degeneracy. [3]

B) Using Operator method, obtain general expression for Eigen functions of one dimensional harmonic oscillator. [6]