Total number of printed pages–7

3 (Sem–5/CBCS) PHY HC 1

2023

PHYSICS

(Honours Core)

Paper : PHY–HC–5016

(Quantum Mechanics and Applications)

Full Marks : 60

Time : Three hours

The figures in the margin indicate full marks for the questions.

1. Answer the following questions : 1×7=7

   (a) Why eigenvalues and eigenfunctions of Hermite operators are very important for a quantum physicist?

   (b) Stationary states are those for which the probability density ρ is

      (i) time-dependent

      (ii) time-independent

      (iii) space-dependent

      (iv) space-independent

Contd.

(c) Starting from time independent Schrödinger equation in polar coordinate for hydrogen atom, show that for azimuthal angle, the probability density of electron is constant. What is its significance?

(d) A particle in the ground state is located in one dimensional potential well of width L with absolutely impenetrable walls $0 < x < L$. Find probability of finding the particle in the region $\frac{L}{3} < x < \frac{2L}{3}$.

(e) What are identical particles? Show that when two identical particles try to occupy same quantum state, then anti-symmetric wave function becomes zero. Why Pauli's exclusion principle is not valid for Bosons? 1+3+1=5

4. Answer ***any three*** of the following questions: 10×3=30

(a) (i) Explain the meaning of probability current density for a quantum system. Deduce an expression for the probability current density for three dimensional motion and the law of conservation of probability density. 1+3+1=5

(ii) The wave function of a particle moving in one dimension is given to be

$$\psi(x) = \begin{cases} \sqrt{\frac{15}{a}} A\left(a^2 - x^2\right) & \text{for } -a \le x \le 0 \\ 0 & \text{for } |x| > a \end{cases}$$

Find the value of A that will normalise $\psi(x)$ and calculate the expectation values of x and p. 1+2+2=5

[where the notations have their usual meaning.]

(b) (i) For a linear harmonic oscillator, obtain the ground state wave function. Make a plot of the first and second energy eigenfunctions. 7+1=8

(ii) Compare the ground state classical and quantum mechanical probability of the oscillator. What happens when the quantum numbers become very large? 2

(c) From the polar equation of hydrogen atom separate the radial part and using Frobenius method find the energy states. 3+7=10

(d) (i) What is Zeeman effect? Give the explanation of normal Zeeman effect on the basis of classical theory and obtain an expression for Zeeman shift. 1+5=6

(ii) Explain why normal Zeeman effect occurs only in atoms with even number of electrons. 2

(iii) An spectrometer can resolve spectral lines separated by $0{\cdot}03nm$. How much magnetic field will have to be applied to a source of $422{\cdot}7nm$ line, so that the triplet is just resolved in normal Zeeman effect? 2

(e) Differentiate between L-S and J-J coupling schemes.

The wavelengths of D lines of sodium are $5896Å$ and $5890Å$. Calculate the (a) energy of the levels from which these spectral lines originate (b) separation in eV between the two p-levels in sodium atom. Given that the ionisation energy of sodium is equal to $5{\cdot}13eV$. 5+5=10

(f) Describe Stern-Gerlach experiment with a suitable diagram and explain on the basis of quantum theory.

In a Stern-Gerlach experiment silver atoms traverse a distance $0{\cdot}1m$ in a non-homogeneous field of gradient 55 Tesla m^{-1}. If the velocity of silver atom is $450ms^{-1}$, calculate the separation between the two traces on the collector plate.

[Bohr magneton = $9{\cdot}27 \times 10^{-24}JT^{-1}$, Mass of silver atom = $1{\cdot}79 \times 10^{-25}kg$]

3+5+2=10

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