2020

PHYSICS — HONOURS

Paper : CC-11

Full Marks : 50

The figures in the margin indicate full marks.

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

Answer ***question no.*** **1** and ***any four*** from the rest.

1. Answer ***any five*** questions : 2×5

(a) The 2p state for hydrogen atom is known to be $re^{-r/2a_0}(\cos\theta)$. Find out the expectation value of r in this state.

(b) Find the eigenfunction and eigen value of the operator $\frac{d}{d\theta}$, assuming the eigenfunction to be single valued in θ, i.e. $f(\theta+2\pi)=f(\theta)$.

(c) Prove that energy eigenfunction of free particle is doubly degenerate.

(d) In Stern Gerlach experiment why is it necessary to use a beam of neutral atoms and not of ions?

(e) What is Paschen Back effect?

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

(g) Find out the magnetic moment of an atom in the state ${}^2D_{3/2}$.

2. (a) Show that Fourier transform of a Gaussian wave function is also Gaussian.

(b) Consider a linear harmonic oscillator for which the total energy is given by $E=\frac{p_x^{\,2}}{2m}+\frac{1}{2}m\omega^2x^2$. where the symbols have their usual meanings. The particle is assumed to be confined to a region $\sim a$. Use the uncertainty principle to obtain the minimum (ground state) of the oscillator.

(c) An electron of energy 342 eV is confined in one-dimensional box of length 1 Å. Find out the quantum number of the energy level of the electron and energy needed to excite it in the next higher level. 4+3+3

3. (a) If a particle is confined between $-\frac{l}{2}$ to $+\frac{l}{2}$, show that there will be two sets of energy eigenfunctions depending on whether n is odd or even.

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(b) A particle in the infinite square well has the initial wave function $\psi(x, 0) = \begin{cases} Ax, & 0 \le x \le a/2 \\ A(x-a), & a/2 \le x \le a \end{cases}$

Find $\psi(x, t)$.

(c) Find the quantum number corresponding to an oscillator of mass 2 gm, angular velocity 1 rad/sec, amplitude 1 cm and using correspondence principle comment on its nature. 4+4+2

4. (a) Write down the Schrödinger equation for the electron of Tritium (H_3) atom, assuming the nucleus to be stationary. Obtain the radial equation by separation of variables with special emphasis on effective potential.

(b) The wave function of hydrogen atom is $\psi(\vec{r}, 0) = \frac{1}{\sqrt{10}}\left(2\psi_{100} + \psi_{210} + \sqrt{2}\,\psi_{211} + \sqrt{3}\,\psi_{21-1}\right)$

Find out the expectation value for the energy, L^2 and L_z of this system. 4+(2+2+2)

5. (a) The wave function corresponding to the first excited state of a harmonic oscillator of frequency ω_0 is given by $\psi(x) = Axe^{-\alpha x^2/2}$; $\alpha = m\omega_0/\hbar$. Sketch $\psi(x)$ and determine A.

(b) Find the expectation value of the operator xp_x in this state.

(c) Find $\langle \hat{S}_z \rangle$ in the state $\chi = A\begin{pmatrix} 1-2i \\ 2 \end{pmatrix}$. (1+2)+4+3

6. (a) Write down the fine-structure formula mentioning each correction term with respect to the Bohr energy for hydrogen atom.

(b) Using first-order perturbation theory, obtain the relativistic correction term to the kinetic energy.

(c) Find the g-value for $^3S_1$ and $^3P_1$ energy levels. Draw the schematic diagram of various allowed transmissions between the above levels due to anomalous Zeeman effect. 3+3+4

7. (a) For normal Zeeman effect of hydrogen, explain how Lorentz triplet occurs. How are the π and σ lines polarized?

(b) The quantum numbers of two electrons in a two electron atom are

$l_1 = 3,\ S_1 = \frac{1}{2}$ and $l_2 = 2,\ S_2 = \frac{1}{2}$.

(i) Assuming LS coupling, find the possible values of L and hence J.

(ii) Assuming JJ coupling, find the possible values of J. (3+2)+(3+2)