

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  $\theta$ , 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  $E = \frac{p_x^2}{2m} + \frac{1}{2}m\omega^2 x^2$ .

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  $1 \text{ \AA}$ . 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  $\psi(x, 0) = \begin{cases} Ax, & 0 \leq x \leq a/2 \\ A(x-a), & a/2 \leq x \leq a \end{cases}$

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  $\psi(\vec{r}, 0) = \frac{1}{\sqrt{10}} (2\psi_{100} + \psi_{210} + \sqrt{2}\psi_{211} + \sqrt{3}\psi_{21-1})$

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  $\omega_0$  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  $\pi$  and  $\sigma$  lines polarized?

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

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

- (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)