Total number of printed pages–7

63/1 (SEM–5) CC11/PHYHC5116

2024

PHYSICS

Paper : PHYHC5116

(Quantum Mechanics and Applications)

Full Marks : 60

Pass Marks : 24

Time : Three hours

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

1. Choose the correct option from the following : ***(any five)*** $1 \times 5 = 5$

   (a) Schrödinger's wave equation for a moving particle contains

   (i) first order time derivative

   (ii) second order time derivative

   (iii) third order time derivative

   (iv) no time derivative

Contd.

(b) The probability of finding a particle at distance dx around a point x is

(i) ψ^*

(ii) $\psi^* \psi \, dx$

(iii) $\psi^* \psi$

(iv) $\psi^* \psi \; xdx$

(c) The Hamiltonian operator is the operator associated with

(i) linear momentum

(ii) position

(iii) energy

(iv) angular momentum

(d) A wave packet travels with

(i) phase velocity

(ii) zero velocity

(iii) group velocity

(iv) velocity of light

(e) One Bohr magneton is defined as

(i) $\mu_B = {eh}/{2m}$

(ii) $\mu_B = {\hbar}/{2m}$

(iii) $\mu_B = {2e\hbar}/{m}$

(iv) $\mu_B = {e\hbar}/{2m}$

(f) The splitting of a spectral line in the presence of external electric field is termed as

(i) Anomalous Zeeman effect

(ii) Paschen Black effect

(iii) Normal Zeeman effect

(iv) Stark effect

(g) In normal Zeeman effect a level of given l splits into

(i) l levels

(ii) $2l$ levels

(iii) $(2l + 1)$ levels

(iv) $(2l - 1)$ levels

(h) The value of spin quantum number of an electron in hydrogen atom is

(i) $-\frac{1}{2}$

(ii) $+\frac{1}{2}$

(iii) 1

(iv) 0

(i) L-S coupling is usually observed in atom with

(i) low atomic number

(ii) high atomic number

(iii) one valance electron

(iv) moderate atomic number

(j) The first experiment that confirmed the presence of electron spin was

(i) Young's double-slit experiment

(ii) Stern-Gerlach experiment

(iii) Davisson-Germer experiment

(iv) Rutherford experiment

2. Answer the following questions : ***(any five)*** 2×5=10

(a) Why is the schrödinger equation invalid for relativistic particles?

(b) What are Eigenvalues and Eigen-functions?

(c) What is the Bohr's interpretation of a wave function?

(d) Define the term 'expectation value'.

(e) What is Lande's g-factor? Write the expression for it.

(f) An atom is placed in a magnetic field of strength $0.1T$. Calculate the rate of precision.

(g) What is Paschen-Back effect?

3. Answer ***any five*** of the following : 5×5=25

(a) Explain normalization of a wave function. Find the normalization constant of a particle described by the Gaussian wave packet wave function.

$$\psi(x) = Ae\frac{-\alpha^2 x^2}{2}.\ e^{ikx} \text{ in all space.}$$

2+3=5

Contd.

(b) Define 'Operator'. Derive expression for

(i) linear momentum operator

(ii) Energy operator 1+2+2=5

(c) Find the expectation value of position and momentum of a particle whose normalized wave function is,

$$\psi(x) = \frac{1}{\sqrt{2a}}.e^{i(kx-\omega f)} \text{ in the interval } (-a, a)$$

(d) For a free particle, show that the group velocity of the wave packet is equal to the classical velocity of the particle.

(e) Show that

(i) $[x, p_x] = i\hbar$

(ii) $[y, p_x] = 0$

(f) What is Gaussian wave packet? Explain its various properties.

(g) What is Bohr magneton? How does it prove the quantization of magnetic moment? 1+4=5

(h) What is Zeeman effect? Differentiate between normal and anomalous Zeeman effect. 1+4=5

(i) What is J-J coupling? Explain J-J coupling in case of two-electron system. 1+4=5

4. Answer ***any two*** of the following : 10×2=20

(a) Determine the energy eigenvalues of a particle in a one-dimensional potential well of finite depth.

(b) Derive an expression for the total magnetic moment of an electron and Lande's g-factor. Calculate Lande's g-factor for p-electron. 7+3=10

(c) Describe Stern-Gerlach experiment. What is its quantum mechanical explanation? 7+3=10

(d) Coulomb's potential energy of an electron at a distance r from the nucleus of a hydrogen atom $V = {-e^2}/{4\pi\varepsilon_0 r}$ substituting this value of V in Schrödinger's steady state equation obtain three independent equations in three different spherical polar co-ordinates r, θ and ϕ. Write down the normalised solutions of each equation. 7+3=10