2024/11

SET A

B.SC. PHYSICS
FIFTH SEMESTER
QUANTUM MECHANICS
BSP – 501

[USE OMR FOR OBJECTIVE PART]

Duration: 3 hrs. **Full Marks: 70**

(Objective)

Time: 30 min. **Marks: 20**

Choose the correct answer from the following: ***1×20=20***

1. If the momentum of a particle is doubled, its De Broglie wavelength will
   a. Remain the same
   b. Be halved
   c. Be doubled
   d Be quadrupled

2. Which principle is the De Broglie wavelength associated with
   a. Uncertainty Principle
   b. Wave-Particle Duality
   c. Conservation of Energy
   d. Relativity Principle

3. According to Planck's law, the energy of a photon is directly proportional to its
   a. Wavelength
   b. Frequency
   c. Amplitude
   d. Speed

4. In the photoelectric effect, if the frequency of incident light is below the threshold frequency, the result will be
   a. Electrons will be ejected with less energy
   b. No electrons will be ejected
   c. Electrons will be ejected with more energy
   d. The metal surface will emit light

5. In the time-independent Schrödinger wave equation, what does the symbol ψ represent?
   a. Momentum of the particle
   b. Position of the particle
   c. Probability density
   d. The wave function of the system

6. The time-dependent Schrödinger wave equation is $i\hbar\frac{\partial\varphi}{\partial t} = \hat{H}\varphi$. What does $\hat{H}$ represent
   a. Momentum operator
   b. Kinetic energy operator
   c. Hamiltonian operator (total energy operator)
   d. Potential energy operator

7. The particle in a one-dimensional infinite potential well can have zero energy in which of the following states
   a. Only in the ground state
   b. the first excited state
   c. n the infinite number of excited states
   d. The particle cannot have zero energy in any state

8. What is the mathematical representation of a quantum system's state?
   a. Hamiltonian
   b. Wave function
   c. Lagrangian
   d. Schrödinger equation

9. What does the square of the absolute value of a wave function, $|\Psi|^2$, represent?
   a. The energy of the particle
   b. The probability density of finding a particle at a given position
   c. The momentum of the particle
   d. The time evolution of the system

10. What is the significance of the normalization condition of a wave function?
   a. It ensures the wave function is purely real.
   b. It ensures the probability of finding the particle somewhere in space is 1
   c. It makes the wave function time-independent
   d. It guarantees the energy is always conserved

11. Hamiltonian of a system is given by
   a. p.v-L
   b. p-vL
   c. pL-v
   d. pv+L

12. Momentum operator p in 1-D is
   a. $i\hbar\partial/\partial x$
   b. $i\partial/\hbar\partial x$
   c. $\partial/\ i\hbar\partial x$
   c. None of the Above

13. For a charged particle Q in an electromagnetic field, the force experienced is given by
   a. Q[E+ v x B]
   b. E[Q+ v x B]
   c. Q[B+ v x E]
   d. Q[v+ E x B]

14. The principal quantum number 'n' is given by
   a. $j_{max}+l+1$
   $j_{max}- l +1$
   c. $j_{max}+ l -1$
   $j_{max}- l -1$

15. Electrons has a value of 's' given by
   a. 0
   b. 1/2
   c. 1
   d. 2

16. _____are finite at origin but the _____ are otherwise.
   a. Bessel functions, Neumann functions
   b. Laguerre polynomial, Neumann functions
   c. Bessel functions, Legendre polynomial
   d. Neumann functions Bessel functions,

17. Kinematic correction in terms of spin-orbit coupling is called
   a. Larmor precession
   b. Thomas precession
   c. Gyro precession
   d. none of the above

18. In presence of spin-orbit coupling,
   a. L and S are separately conserved
   b. J is not conserved
   c. L is conserved, S is not
   d. S is conserved, L is not.

19. For n=1, l=0 j=1/2, Lande's g-factor splits into
    a. 1 component
    b 2 components
    c. 3 components
    d 4 components

20. Hyperfine splitting of ground state of H is due to
    a. Spin-orbit coupling
    b Orbit -orbit coupling
    c. Spin-Spin coupling
    d All of the above

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Descriptive

Time : 2 hrs. 30 mins. **Marks : 50**

[Answer question no.1 & any four (4) from the rest]

1. a. Prove that in the photo-electric effect from a metal surface, the maximum velocity of the photo-electrons is related to the stopping potential by the equation $V_{max} = 5.927 \times 10^5 \sqrt{V_0}$, where V_{max} is in m/s and V_0 is in volts. **5+5=10**

   b. Find the lowest energy of a neutron confined to a nucleus of size 10^{-14} m. Given, mass of the neutron= 1.67×10^{-27} kg.

2. a. Obtain the Kinetic energy operator from momentum operator. **5+5=10**

   b. State the postulates of quantum mechanics.

3. Obtain Wein's displacement law and Stefan-Boltzmann law from Plank's law. **5+5=10**

4. Solve the Schrodinger wave equation for a particle moving in an infinitely deep one- dimensional potential well and obtain its energy level. **7+3=10**

5. Answer the following 3+5+2 =10

   a. Provide the normalization condition for wave function associated with a quantum particle expressed in spherical coordinates?

   b. What are spherical harmonics?

   c. Provide the orthogonality condition of wave-function in terms of spherical coordinates.

6. **a.** Write the expression for the energy of ground state and first excited state of an H atom in terms of principal quantum number 'n'. 2+4+4 =10

   b. Describe how for for n=2, four different states share the same energy.

   c. Elaborate the quantum jumps between initial and final states for an H atom. Define Lyman, Balmer and Paschen Series with the help of an energy level diagram.

7. Elaborate fine structure, lamb shift and hyperfine splitting of Hydrogen spectra. Also draw energy level diagram including fine structure of H-atom. 2+2+2+4 =10

8. Describe in detail the Zeeman effect associated with H-atom. 10

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