REV-01
MSP/41/21/26

2023/01

SET A

M.Sc. PHYSICS
FIRST SEMESTER
QUANTUM MECHANICS
MSP – 101

[USE OMR SHEET FOR OBJECTIVE PART]

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

(Objective)

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

Choose the correct answer from the following: ***1X20=20***

1. The de Broglie wavelength is associated with
   a. charged particles
   b. sub-atomic particles
   c. macroscopic particles
   d. electrically neutral particles
2. Interaction of light with material particles gives______ nature of light
   a. wave
   b. particle
   c. both (a) and (b)
   d. none of these
3. For a very heavy classical particle, which among the following uncertainty relation is true?
   a. $\Delta x.\Delta L_x \sim h$
   b. $\Delta x.\Delta p_x = \infty$
   c. $\Delta x.\Delta V_x = 0$
   d. $\Delta x.\Delta E_x = \lambda$
4. The energy of electron in first-Bohr's orbit is
   a. $-13.6\ eV$
   b. $-3.4\ eV$
   c. $-1.5\ eV$
   d. $-6.0\ eV$
5. The Davision and Germer experiment is related to
   a. interference
   b. reflection
   c. diffraction
   d. polarization
6. The positional uncertainty of a nucleon (particles inside the atomic nucleus) is
   a. $10^{-9}m$
   b. $10^{-12}m$
   c. $10^{-15}m$
   d. $10^{-18}m$
7. de Broglie wavelength of a body of mass 'm' and kinetic energy 'E'(for non-relativistic case) is
   a. $\frac{2mh}{\sqrt{E}}$
   b. $\frac{h}{2mE}$
   c. $\frac{h}{\sqrt{2mE}}$
   d. $\frac{\sqrt{2mE}}{E}$
8. The Schrödinger wave equation is ____ -order in time and _____ -order in space coordinates
   a. first, first
   b. second, second
   c. first, second
   d. second, first
9. If ψ represents a wave function of a particle in a system, $|\psi|^2$ is its
   a. probability
   b. amplitude
   c. probability current density
   d. probability density

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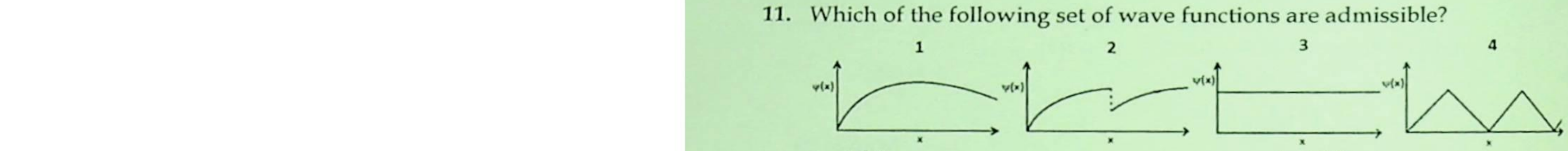
10. In 1D potential well, the spacing between nth energy level and the next higher level is (E_1 is ground state)
   a. nE_1 b. $2nE_1$
   c. $(n+1)E_1$ d. $(2n+1)E_1$

11. Which of the following set of wave functions are admissible?



   a. 1&2 b. 1&3
   c. 2&4 d. 3&4

12. The spectral line series of H-atom which fall in visible range of wavelengthis
   a. Pfund b. Bracket c. Lyman d. Balmer

13. If two different unperturbed states of a quantum system share same energy, then the states are
   a. degenerate b. non-degenerate
   c. both (a) and (b) d. none of these

14. The first order energy correction in time independent perturbation theory is
   a. $E_k^{(1)} = \langle \psi_n^0 | H' | \psi_n^0 \rangle$ b. $E_k^{(1)} = \dfrac{\langle \psi_n^0 | H' | \psi_n^0 \rangle}{E_n^{(0)}}$
   c. $E_k^{(1)} = \dfrac{\langle \psi_n^0 | H' | \psi_n^0 \rangle}{E_m^{(0)} - E_n^{(0)}}$ d. none of these

15. Stark effect occurs in presence of an/a
   a. electric field b. magnetic field
   c. gravitational field d. strong nuclear field

16. The first order perturbed Hamiltonian, when an external uniform electric field is E is applied in z-axis of an atom is (p stands for dipole moment, E for external electric field)
   a. $H' = \vec{p}.\vec{E}$ b. $H' = -\vec{p}.\vec{E}$
   c. $H' = \vec{E}/\vec{p}$ d. $H' = \vec{p}/\vec{E}$

17. The variational principle gives a/an ________ value for ground state energy level
   a. upper bound b. lower bound
   c. both (a) and (b) d. none of these

18. In variational method the constant α appear in trail wave function is evaluated by considering the following relation
   a. $\dfrac{\partial \langle E \rangle}{\partial \alpha} = 1$ b. $\dfrac{\partial \langle E \rangle}{\partial \alpha} = 0$
   c. $\dfrac{\partial \langle E \rangle}{\partial \alpha} = \infty$ d. $\dfrac{\partial \langle E \rangle}{\partial \alpha} = \dfrac{1}{e}$

19. The ground state energy of a He-atom physically represents the amount ofenergy it would spend for
   a. strip off an electron b. strip off both the electrons
   c. counter balancing e-e repulsion d. avoiding Pauli's exclusion principle

20. In laboratory frame the ground state energy for He atom is precisely calculated as
   a. $-13.6\ eV$ b. $-34\ eV$
   c. $-79\ eV$ d. $-109\ eV$

(Descriptive)

Time : 2 hrs. 30mins. Marks : 50

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

1. Write the statement of the de Broglie hypothesis. Discuss the proof of matter waves by Davision & Germer experiment **2+8=10**

2. a. Calculate the de Broglie wavelength of an electron having a kinetic energy of 1000 eV. (Given: $h=6.63\times10^{-34}$Js). **5+5=10**

   b. An electron has a speed of 500 m/s with an accuracy of 0.004%. Calculate the certainty with which one can locate the position of the electron.

3. Write the statement of Heisenberg's Uncertainty Principle and establish the non-existence of free electrons inside a nucleus. **2+8=10**

4. Solve the Schrodinger's wave equation for a particle moving in a one-dimensional potential box with rigid walls. Obtain its energy levels and give graphical representation of the discrete energy Eigen values. **6+4=10**

5. a. Find the lowest energy of a neutron confined to a nucleus of size 10^{-14}m. (Given: $\hbar = 1.054 \times 10^{-34}$Js, Mass of neutron $= 1.67 \times 10^{-27} kg$). **5+5=10**

   b. Normalize the one-dimensional wave function given by

   $\psi_n = A\, sin(\pi x/a)$ for $0 < x < a$

   $\psi_n = 0$ otherwise

6. a. The unperturbed wave function for the infinite square well is given by $\psi_n^0(x) = \sqrt{\frac{2}{a}} sin\left(\frac{n\pi x}{a}\right)$ and the Eigen value is $E_n^0 = \frac{n^2\pi^2\hbar^2}{2ma^2}$. If the system is perturbed simply by raising the floor of the well by a constant amount $V(x) = V_0$, determine the total energy with corrective term. **5+5=10**

   b. Prove that the hydrogen atom in the ground state DOES NOT show a first-order Stark effect

7. If a system with an unperturbed Hamiltonian H_0 is subjected to a perturbation H_p where **10**

$$H_0 = E_0 \begin{bmatrix} 15 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 \\ 0 & 0 & 3 & 0 \\ 0 & 0 & 0 & 3 \end{bmatrix}, \text{ and } H_p = \frac{E_0}{100} \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

then find the energy Eigen values corrected to the first order.

8. What are Einstein's A & B coefficients? Establish the relation between these coefficients. **2+8=10**

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