REV-01
MSP/15/20

2023/12

SET A

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

[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. Interaction of light with material particles gives______ nature of light

   a. wave b. particle
   c. both (a) and (b) d. none of these

2. The Davision and Germer experiment is related to

   a. interference b. reflection
   c. diffraction d. polarization

3. For a very heavy classical particle, which among the following uncertainty relation is true?

   a. $\Delta x.\Delta L_x \sim h$ b. $\Delta x.\Delta p_x = r$
   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. Quantum Mechanically, the energy states of a simple harmonic oscillator are

   a. continuous b. partially continuous
   c. discrete d. all of these

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. $\frac{\sqrt{2mE}}{E}$

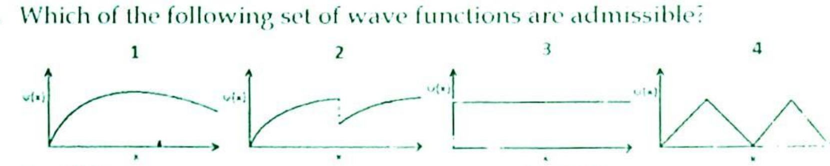
8. The Schrödinger wave equation is ______-order in time and ______-order in space coordinates

   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

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 wavelength is
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. $E_k^{(1)} = \frac{\langle\psi_n^0|H'|\psi_n^0\rangle}{E_n^{(0)}}$
c. $E_k^{(1)} = \frac{\langle\psi_m^0|H'|\psi_n^0\rangle}{E_m^{(0)}-E_n^{(0)}}$
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. Separation between two adjacent energy-levels in simple harmonic oscillator is.
a. $\frac{1}{2}\hbar\omega$
b. $\hbar\omega$
c. $\frac{1}{\hbar\omega}$
d. $2\hbar\omega$

18. A system is called degenerate; if a number orthogonal Eigen function corresponds to ______ energy eigen value(s).

a. same
b. different
c. same or different
d. None of these

19. In a Gaussian trail function given by $\psi = A\,e^{-\alpha x^2}$, the normalization constant is equal to

a. $\frac{2\alpha}{\pi}$
b. $\sqrt{\frac{2\alpha}{\pi}}$
c. $\left(\frac{2\alpha}{\pi}\right)^{1/4}$
d. $\sqrt{\frac{\pi}{2\alpha}}$

20. Zero point energy of a one dimensional harmonic oscillator is

a. $E=mc^2$
b. $E=nKT$
c. $E=h\upsilon/2$
d. $E=e^2/4\pi\varepsilon_0 r$

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Descriptive

Time : 2 hrs. 30 min. Marks : 50

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

1. Write the statement of Heisenberg's Uncertainty Principle and establish the non-existence of free electrons inside a nucleus. 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 the de Broglie hypothesis. Discuss the proof of matter waves by Davision & Germer experiment. 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. 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. Using the time independent Schrödinger equation show that the lowest energy of a simple harmonic oscillator is $E_0 = \frac{1}{2}\hbar\omega$. 10

7. a. What you understand by perturbation in quantum systems? Write the first order perturbation correction to energy for a non degenerate system. 5+5=10
   b. If the unperturbed wave function of an infinite square well is given by $\psi_n^0(x) = \sqrt{\frac{2}{a}}\sin\left(\frac{n\pi x}{a}\right)$, and if the system is perturbed simply by raising the floor half way across the wall by a constant amount V_0. Calculate the first order correction to the energy of the system.

8. 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 potential change $V(x) = \frac{V_0 x}{a}$, where V_0 is a small constant. Determine the total energy with corrective term. 5+5=10
   b. If a perturbation like a delta function appears at the centre of an infinite potential well, $H' = \alpha\delta\left(x - \frac{a}{2}\right)$, where α is a constant added to an infinite square well potential, and a is the width, then find the first order correction to the allowed energies.

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