

M.Sc. PHYSICS
FIRST SEMESTER
QUANTUM MECHANICS
MSP-101 [REPEAT]
[USE OMR FOR OBJECTIVE PART]

**SET
A**

Duration: 3 hrs.

Full Marks: 70

Time: 30 min.

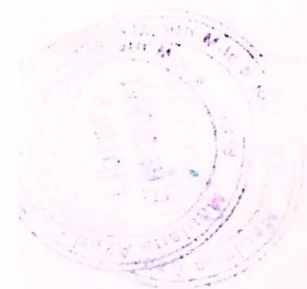
Marks: 20

(Objective)

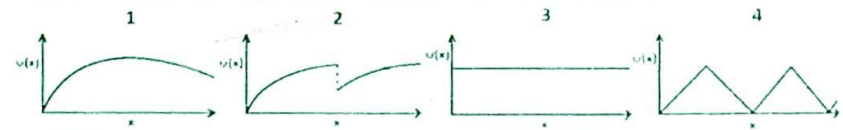
1×20=20

Choose the correct answer from the following:

- Interaction of light with material particles gives _____ nature of light
 - wave
 - particle
 - both (a) and (b)
 - none of these
- The Davison and Germer experiment is related to
 - interference
 - reflection
 - diffraction
 - polarization
- For a very heavy classical particle, which among the following uncertainty relation is true?
 - $\Delta x \cdot \Delta p_x \sim h$
 - $\Delta x \cdot \Delta p_x = \epsilon$
 - $\Delta x \cdot \Delta V_x = 0$
 - $\Delta x \cdot \Delta E_x = \lambda$
- The energy of electron in first-Bohr's orbit is
 - 13.6 eV
 - 3.4 eV
 - 1.5 eV
 - 6.0 eV
- Quantum Mechanically, the energy states of a simple harmonic oscillator are
 - continuous
 - partially continuous
 - discrete
 - all of these
- The positional uncertainty of a nucleon (particles inside the atomic nucleus) is
 - $10^{-9}m$
 - $10^{-12}m$
 - $10^{-15}m$
 - $10^{-10}m$
- De Broglie wavelength of a body of mass 'm' and kinetic energy 'E' (for non-relativistic case) is
 - $\frac{2mh}{\sqrt{E}}$
 - $\frac{h}{2mE}$
 - $\frac{h}{\sqrt{2mE}}$
 - $\frac{h}{E}$
- The Schrödinger wave equation is _____ -order in time and _____ -order in space coordinates
 - first, first
 - second, second
 - first, second
 - 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 n th 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. Brackett
 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. $E_k^{(1)} = \frac{\langle \psi_n^0 | H' | \psi_n^0 \rangle}{E_m^{(0)} - E_n^{(0)}}$
 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. $H' = \vec{p} \cdot \vec{E}$
 b. $H' = -\vec{p} \cdot \vec{E}$
 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 trial 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. $E=kT$
c. $E=h\nu/2$
d. $E=e^2/4\pi\epsilon_0 r$

(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: $h=6.63 \times 10^{-34}$ 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: $h = 1.054 \times 10^{-34}$ Js, Mass of neutron = 1.67×10^{-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 $E_0 = \frac{1}{2} h\omega$. 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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