QP CODE: 24044703 24044703

Reg No : ....

Name : ....

M.Sc DEGREE (CSS) EXAMINATION, OCTOBER 2024

Third Semester

CORE - PH010301 - QUANTUM MECHANICS-II

M.Sc PHYSICS, M.SC SPACE SCIENCE

2019 ADMISSION ONWARDS

72CCC5FA

Time: 3 Hours Weightage: 30

Part A (Short Answer Questions)

*Answer any **eight** questions.*

*Weight **1** each.*

1. Write down the second order correction for energy in perturbation theory and explain the terms therein.
2. What is a Gaussian trial wave function in variational method? Why is it suitable as a trial wavefunction for harmonic oscillator problem?
3. Briefly discuss how WKB method can be used to analyze alpha decay problem.
4. Show that the time evolution operator in the interaction picture obeys $U_I(t_2, t_0) = U_I(t_2, t_1)U_I(t_1, t_0)$ for three instants of times $t_0 < t_1 < t_2$.
5. A constant perturbation V_0 is applied during $0 \leq t \leq t_1$ to system in an energy level E_1. Plot of the probability to find it at time t_1 in another energy level E_2 as a function of t_1.
6. State true or false : Partial wave expansion is most useful when incoming beam has low momentum. Justify your answer with reason.
7. What is the SI unit for scattering cross section?
8. Discuss the validity condition for Born approximation.
9. Is Klein-Gordon equation Lorentz invariant? Give reason.
10. Does Dirac equation have the same form for all inertial observers? Justify your answer

(8×1=8 weightage)

Part B (Short Essay/Problems)

*Answer any **six** questions.*

*Weight **2** each.*

11. A particle experiences a two dimensional potential well described by the potential

$$V(x,y) = \begin{cases} 0 & \text{for } 0 < x < L\,; 0 < y < L; \\ \infty & \text{elsewhere.} \end{cases}$$

Find the energy correction to the degenerate first excited level when it is perturbed by $H' = \alpha\,\delta(x - L/6)\,\delta(y - L/4)$ where $\alpha > 0$ is a constant.

Given, the wavefunctions corresponding to the doubly degenerate first excited state :

$\psi_1(x,y) = \frac{2}{L} sin\left(\frac{2\pi x}{L}\right) sin\left(\frac{\pi y}{L}\right)$ and $\psi_2(x,y) = \frac{2}{L} sin\left(\frac{\pi x}{L}\right) sin\left(\frac{2\pi y}{L}\right)$.

12. A particle is in a one dimensional potential of the form $V(x) = \alpha|x|$. Using WKB method find how the energy of the particle
depends on quantum number n.

13. A particle in one dimension moves in a potential $V(x) = V_0\left(1 - e^{-\frac{(x-x_0)^2}{2\sigma^2}}\right)$ where V_0, x_0 and σ are positive real constants. If the energy E of the particle is $E < V_0$, find the turning points and write down the wavefunctions representing the state of the particle in the regions away from the turning points.

14. A harmonic oscillator is in a superposed state of its ground state, first and second excited states given by $|\psi(t=0)\rangle_S = \frac{1}{2}\left(|0\rangle - \sqrt{2}|1\rangle + |2\rangle\right)$ at time $t = 0$. Find the state $|\psi(t)\rangle_I$ at time t in the interaction picture. Is it the same as the state $|\psi(t)\rangle_S$ in Schrodinger picture? (Given n^{th} energy level $E_n = (n + \frac{1}{2})\hbar\omega$.)

15. What is electric dipole approximation. How this approximation simplify the expression for absorption cross section in the interaction of atom with classical electromagnetic field.

16. Construct symmetric and antisymmetric wave functions for a system of three identical non interacting particles.

17. Investigate scattering by a hard sphere using the method of partial waves.

18. How does Dirac's hole theory explain the negative energy states?

(6×2=12 weightage)

Part C (Essay Type Questions)

*Answer any **two** questions.*

*Weight **5** each.*

19. Discuss the estimation of ground state energy of Hydrogen molecule ion using variational technique.

20. Derive an expression for absorption cross-section for a system in which an atomic electron interacts with classical electromagnetic fields

21. Using Born approximation, evaluate the scattering amplitude for a screened Coulomb potential $V(r) = -(\frac{Ze^2}{r})\ \exp(-ar)$ where a is a constant. Obtain the Rutherford formula for Coulomb scattering from this.

22. Obtain Schrodinger equation as a non-relativistic limit of Dirac equation.

(2×5=10 weightage)