QP CODE: 21000414

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Reg No : .....

Name : .....

M Sc DEGREE (CSS) EXAMINATION, MARCH 2021

Third Semester

Faculty of Science

M Sc PHYSICS

CORE - PH010301 - QUANTUM MECHANICS-II

2019 Admission Onwards

FA27F923

Time: 3 Hours Weightage: 30

Part A (Short Answer Questions)

*Answer any **eight** questions.*

*Weight **1** each.*

1. Write and explain the interaction term in the Helium atom hamiltonian.
2. Write down the quantization conditions obtained from WKB method in problems with one infinite vertical wall and two infinite vertical walls.
3. Briefly discuss how WKB method can be used to analyze alpha decay problem.
4. Write down Dyson series expansion for the time evolution operator in interaction picture and explain terms therein.
5. Plot the probability for transition of a system between two of its energy levels E_1 and E_2 under a constant perturbation applied for time t as a function of energy difference $(E_2 - E_1)$.
6. What are symmetric and antisymmetric wave functions?
7. What is scattering amplitude?
8. Write down the expression for the scattering amplitude in Born approximation and express the scattering cross section in the approximation.
9. Does Schrodinger's equation have the same form for all inertial observers? Give reason.
10. Find the traces of the Dirac matrices $(\boldsymbol{\alpha}, \beta)$.

(8×1=8 weightage)

Part B (Short Essay/Problems)

*Answer any **six** questions.*

*Weight **2** each.*

11. A system with hamiltonian H_0 has two eigenstates $|1\rangle \text{ and } |2\rangle$ with same energy value E. This system is perturbed by a hamiltonian $H' = \epsilon\,|1\rangle\langle 2| - 4\epsilon\,|2\rangle\langle 1|$ where ϵ is a constant with dimensions of energy. Find the first order correction to the states $|1\rangle \text{ and } |2\rangle$.

12. Using Gaussian $\psi(x) = \left(\frac{2b}{\pi}\right)^{\frac{1}{4}} e^{-bx^2}$ trial wavefunction estimate the ground state energy of a particle in a potential $V(x) = -\alpha\, x^4$ where α is a constant.
(Given : $\int_0^\infty dx\; x^2 e^{-2bx^2} = -\frac{1}{2}\frac{d}{db}\int_0^\infty dx\; e^{-2bx^2}$)

13. Find how the energy eigen values of a Half harmonic oscillator depend on the quantum number n using WKB method?

14. Compare Schrodinger, Heisenberg and interaction pictures.

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. Use Born approximation to obtain differential scattering cross section when a particle moves in the potential $V(r) = -V_0 exp(\frac{-r}{r_0})$ where V_0 and r_0 are positive constants. Given $\int_0^\infty dr\; r\; e^{-ar} \sin br \;=\; \frac{2ab}{(a^2+b^2)^2}$.

17. Calculate the scattering cross section for the Yukawa potential $V(r) = V_0 \frac{e^{-\alpha r}}{r}$ where V_0 and α are constants. Show that for $\alpha \to 0$, cross section $\sigma(\theta)$ corresponds to that of Rutherford scattering.

18. Show that positive and negative energy solutions of Dirac equation with same momentum $\mathbf{p}$ are orthogonal.

(6×2=12 weightage)

Part C (Essay Type Questions)

*Answer any **two** questions.*

*Weight **5** each.*

19. Discuss the time independent perturbation theory and obtain expressions for first order correction in wavefunction.

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

21. Apply the method of partial waves to study the scattering of a particle by a hard sphere and show that (i) For incident particles of low energy, the s-wave scattering is predominant. (ii) For large energy incident particles, the total scattering cross section is half of that for low energy particles.

22. Show that orbital angular momentum $\mathbf{L}$ will not be conserved for a free Dirac particle. Show further that total angular momentum $\mathbf{L}+\mathbf{S}$ will be conserved where $\mathbf{S}=\frac{1}{2}\hbar\begin{bmatrix}\boldsymbol{\sigma} & 0\\ 0 & \boldsymbol{\sigma}\end{bmatrix}$ is the spin vector.

(2×5=10 weightage)