QP CODE: 23144684

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Reg No : .....

Name : .....

M Sc DEGREE (CSS) EXAMINATION, NOVEMBER 2023

Third Semester

Faculty of Science

CORE - PH010301 - QUANTUM MECHANICS-II

M Sc PHYSICS, M Sc SPACE SCIENCE

2019 ADMISSION ONWARDS

7BAFDEAF

Time: 3 Hours Weightage: 30

Part A (Short Answer Questions)

*Answer any **eight** questions.*

*Weight **1** each.*

1. Can a perturbation in the form of a constant potential remove the degeneracy of energy eigenvalues of any system? Justify your answer.
2. Write the Hamiltonian for the Helium atom and explain the terms therein.
3. How can we find tunneling amplitude using WKB method?
4. Obtain the expression for time evolution of an observable in interaction picture.
5. Write an expression for transition rate for system under a constant perturbation.
6. What are bosons?
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. Write down the wavefunction for a free Dirac particle with momentum $\mathbf{p}$, positive energy and a spin value $S_z = -\frac{\hbar}{2}$.
10. What are the eigenvalues of the operator $\Lambda_+ = \left(\frac{1}{2} + \frac{c\boldsymbol{\alpha}\cdot\mathbf{p}+mc^2\beta}{2\sqrt{c^2p^2+m^2c^4}}\right)$?

(8×1=8 weightage)

Part B (Short Essay/Problems)

*Answer any **six** questions.*

*Weight **2** each.*

11. Write down the Hamiltonian of harmonic oscillator which is subjected to a constant electric field. How can we use perturbation theory in it?

12. Using Gaussian $\psi(x) = \left(\frac{2b}{\pi}\right)^{\frac{1}{4}} e^{-bx^2}$ as the trial wavefunction, estimate the ground state energy of a one dimensional harmonic oscillator.

13. A particle in three dimension experiences a potential of $V(r) = \frac{\alpha}{r^2} - \frac{\beta}{r}$ where $\alpha > 0$ and $\beta > 0$ are constants. If E is the energy of the particle, find the turning points and write down its wavefunction in the regions away from the turning points.

14. A harmonic oscillator of frequency ω in one dimension is in its ground state $|0\rangle$ at time t_0. It is perturbed during $t_0 \leq t \leq t_1$ by a potential $\hat{V}(t) = \epsilon \sum_{n=0}^{\infty} \left(\sqrt{n+1}\ |n+1\rangle\langle n| + \sqrt{n}\ |n-1\rangle\langle n|\right)$ where ϵ is a constant and $|n\rangle$ is the n^{th} energy eigenstate. At first order, find the probability for finding the oscillator in the first excited state $|1\rangle$ at time t_1. [Given n^{th} energy level $E_n = (n + \frac{1}{2})\hbar\omega$]

15. Obtain the rate of transition for an electron from its initial ground state $|i\rangle$ to an excited state $|f\rangle$ due to interaction with a plane electromagnetic wave.

16. The wavefunction describing scattering by a central potential of a beam particles sent parallel to Z-axis in a region $r \to \infty$
$\Psi(\mathbf{r}) = e^{ikz} + \frac{e^{ikr}}{r}\left(\frac{ab}{a^2+b^2} + i\frac{a^2}{a^2+b^2}\right)\cos\theta$
Compute the phase shift δ_1 experienced by the $l = 1$ partial wave (P-wave). Comment on the phase shift experienced by the $l \neq 1$ partial waves ?

17. Prove that $\sigma_{total} = \frac{4\pi}{k}\text{Im}\ f(0)$ where $\text{Im}\ f(0)$ is the imaginary part of the forward scattering amplitude.

18. Show that a wavefunction obeying Klein-Gordon equation cannot always provide a positive probability density.

(6×2=12 weightage)

Part C (Essay Type Questions)

*Answer any **two** questions.*

*Weight **5** each.*

19. What is WKB approximation method. Derive the WKB wavefunction for the non classical region.

20. Apply time dependent perturbation method for an atom interacting with classical electromagnetic field. Use dipole approximation to obtain the absorption cross section.

21. Derive an expression for differential scattering cross section for a scattering experiment by a spherically symmetric potential.

22. Starting from relativistic energy-momentum relation, arrive at Dirac equation by providing necessary arguments. State the relations among Dirac matrices.

(2×5=10 weightage)