QP CODE: 22000732

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Reg No : .....

Name : .....

M Sc DEGREE (CSS) EXAMINATION, APRIL 2022

Third Semester

Faculty of Science

CORE - PH010301 - QUANTUM MECHANICS-II

M Sc PHYSICS, M Sc SPACE SCIENCE

2019 ADMISSION ONWARDS

73DFB9B9

Time: 3 Hours Weightage: 30

Part A (Short Answer Questions)

*Answer any **eight** questions.*

*Weight **1** each.*

1. What is degenerate perturbation theory ?
2. Distinguish the WKB wavefunctions in the classical and non classical regions
3. How can we find tunneling amplitude using WKB method?
4. The Hamiltonian of a system is given by $H = H_0 + V(t)$, where $H_0$is the time independent part. Obtain a differential equation that describes the time evolution of a state ket $|\alpha, t_0; t\rangle_I$ in the interaction picture.
5. An electron is in the ground state of a two-level atom with energy values $E_0 = -7.2\ \mathrm{eV}$ and $E_1 = -2.2\ \mathrm{eV}$. If it interacts with electromagnetic radiation of frequency $\omega = 9.42 \times 10^{16}\ \mathrm{Hz}$, to first order in perturbation, what is the probability to find it in the excited energy level?
6. What is an antisymmetric wave function?
7. Explain Born approximation.
8. What are partial waves in scattering?
9. State the anti-commutation relations for the Dirac matrices $(\boldsymbol{\alpha}, \beta)$.
10. Write down the wavefunction for a free Dirac particle with a momentum p in Y-direction having negative energy and spin value $S_z = -\frac{\hbar}{2}$.

(8×1=8 weightage)

Part B (Short Essay/Problems)

*Answer any **six** questions.*

*Weight **2** each.*

11. The ground state wavefunction of a paticle in a one dimensional potential well $0 \leq x \leq a$ is given by

$\psi(x) = \sqrt{\frac{2}{a}}\, sin(\frac{\pi x}{a})$

Calculate the first order correction in energy when it is perturbed by $H' = \begin{cases} V_0 & \text{for } 0 \le x \le \frac{a}{2}; \\ 0 & \text{for } \frac{a}{2} \le x \le a. \end{cases}$,

where V_0 is a constant.

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 $V(x) = -\alpha\, \delta(x)$ where α is a constant.

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. Consider a particle of mass m bound by a one dimensional harmonic oscillator potential with frequency ω in its ground state. A weak electric field is applied for a time interval T. The perturbation due to electric field is given by $V(t) = eE\, x$ for $0 < t < T$ and zero for all other time. Calculate the probability to make a transition to the first excited state. Given position operator $\hat{x} = \sqrt{\frac{\hbar}{2m\omega}}\,(\hat{a} + \hat{a}^\dagger)$

15. An electron in a photoelectric material has a wavefunction $\psi(\mathbf{r}, t = 0) = \frac{1}{\sqrt{L}} \exp\left(i \frac{p\, x}{\hbar}\right)$ in the region $0 \le x \le L$ and vanishes for all other values of x. If a plane electromagnetic wave $\mathbf{A} = \hat{\mathbf{y}} A_0 \cos\left(\frac{\omega}{c} \hat{\mathbf{z}} \cdot \mathbf{r} - \omega t\right)$ interacts with this electron, what is the probability to find it in a state with higher energy?

16. Use Born approximation to calculate the differential cross section for scattering by the central potential $V(r) = \frac{\alpha}{r^2}$, where α is a constant. Given that $\int_0^\infty \frac{\sin r}{r}\, dx = \frac{\pi}{2}$

17. Obtain the relation between scattering amplitude and scattering cross section.

18. Show that the operators $\Lambda_\pm = \left(\frac{1}{2} \pm \frac{c\boldsymbol{\alpha}\cdot\mathbf{p} + mc^2\beta}{2\sqrt{c^2p^2 + m^2c^4}}\right)$ selects projects stationary states of a free Dirac particle with energy $\pm\sqrt{c^2p^2 + m^2c^4}$ respectively.

(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. Discuss the first order time dependent perturbation theory and derive the Fermi golden rule for the transition rate from a given initial state to final state continuum.

21. Describe the scattering of a charged particle by the Coulomb field of nuclei using the first Born approximation.

22. State relativistic energy momentum relations and arrive at Klein-Gordon equation by providing necessary arguments. Explain why it cannot describe a physical wavefunction.

(2×5=10 weightage)