D 150363 **(Pages : 2)** **Name.....**

Reg. No.....

THIRD SEMESTER M.Sc. (CBCSS) REGULAR/SUPPLEMENTARY DEGREE EXAMINATION, NOVEMBER 2026

Physics

PHY 3C 09—QUANTUM MECHANICS—II

(2019 Admission onwards)

Time : Three Hours Maximum Weightage : 30

Answer the questions as per the instructions given in each section.

Section A

Answer **all** *questions.*
Each question carries 1 *weightage.*

1. What is meant by non-degenerate perturbation theory ?
2. Define second-order energy correction in time-independent perturbation theory.
3. What is meant by degeneracy in quantum mechanics ?
4. State the physical origin of spin orbit coupling.
5. What is the Ritz variational principle ?
6. Define WKB approximation.
7. State Fermi's Golden Rule.
8. What is meant by scattering phase shift ?

(8 × 1 = 8 weightage)

Section B

Answer any **two** *questions.*
Each question carries 5 *weightage.*

9. Develop the theory of non-degenerate time-independent perturbation theory up to second order. Apply it to calculate the first-order energy correction of a linear harmonic oscillator.
10. Explain the Ritz variational method for bound-state problems. Apply it to estimate the ground-state energy of the Helium atom. Discuss briefly the physical significance of the variational principle.
11. Derive the Dirac equation starting from the relativistic energy momentum relation. Discuss the properties of Dirac matrices and show that the Dirac particle has spin 1/2. Obtain the equation of continuity.
12. Give a detailed account of first-order time-dependent perturbation theory for a constant perturbation. Derive Fermi's Golden Rule and discuss transitions to a continuum.

(2 × 5 = 10 weightage)

Turn over

Section C

Answer any **four** *questions.*
Each question carries 3 *weightage.*

13. A hydrogen atom is placed in a weak magnetic field of strength B = 1T. Calcualte the maximum energy splitting of the n = 2 level due to the weak-field Zeeman effect. Take the electron spin g-factor g_s = 2.

14. The hyperfine splitting of the ground state of hydrogen is 5.9 μeV. Calculate the frequency of the corresponding spectral line.

15. Using the variational method with the trial wave function

$$\psi(r) = e^{-\alpha r},$$

estimate the ground-state energy of the Helium atom, neglecting electron-electron correlation. Take the nucleus charge Z = 2.

16. Apply the WKB approximation to a particle of mass m confined in a *finite* one-dimensional potential well of width a and depth V_0. Derive the quantization condition and obtain an expression for the allowed bound-state energy levels.

17. Using the partial-wave method, obtain the expression for the low-energy s-wave scattering cross-section for a particle incident on a spherical square-well potential of depth V_0 and radius a.

18. An electron moves in a uniform magnetic field of strength B = 0.5 T. Using the *non-relativistic limit of the Dirac equation*, estimate the energy difference between the spin-up and spin-down states.

19. A harmonic perturbation $V(t) = V_0 e^{-iwt}$ acts on a two-evel atom with energy separation $\hbar\omega_0 = 2$ eV. Assuming resonance $(\omega = \omega_0)$, use first-order time-dependent perturbation theory to calculate the transition probability per unit time. Take V_0 = 0.01 eV.

(4 × 3 = 12 weightage)