RAN-2403080104011001

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M. Sc. (Sem. - IV) Examination September - 2025

Physics (Paper - PH-541) Advanced Quantum Mechanics (New)

Time: 3 Hours] **[Total Marks: 70**

સૂચના : / Instructions	Seat No.:
(1) ઉપરોક્ત દર્શાવેલ વિગતો ઉત્તરવહી પર અવશ્ય લખવી. Fill up strictly the above details on your answer book. (2) Symbols used have their usual meaning. (3) Figures to the right indicate full marks.	Student's Signature

Q. 1. Attempt any two questions out of the (a), (b) and (c) below.

a. i. Explain the Heisenberg picture and derive its equation of motion. **(05)**

ii. A particle is initially ($t < 0$) in the ground state of an infinite, one- dimensional potential well with walls at $x = 0$ and $x = a$. If the wall at $x = a$ is moved slowly to $x = 8a$, find the energy and wave function of the particle in the new well. Calculate the work done in this process. **(04)**

b. i. Derive the approximate solution in terms of the integral equation in the case of time dependent perturbation theory. **(05)**

ii. Prove that the effect of a harmonic perturbation is to transfer to the system or to receive from it, a photon of energy $h\omega$. **(04)**

c. i. Derive the transition probability in the case of a Sudden Approximation. **(05)**

ii. A particle, which is initially at ($t = 0$) in the ground state of an infinite, one-dimensional potential box with walls at $x = 0$ and $x = a$, is subjected for $0 \le t \le \infty$ to a perturbation $\hat{V}(t) = \hat{x}^2 e^{-t/\tau}$. Calculate to first order the probability of finding the particle in its first excited state for $t \ge 0$. **(04)**

Q. 2. Attempt any two questions out of the (a), (b) and (c) below.

a. i. Derive scattering amplitude, differential cross section and validity condition of the first-order Born approximation. **(05)**

ii. Calculate the differential and total cross sections in the Born approximation for the potential $V(r) = V_0 \dfrac{e^{-r/R}}{r}$, known as the Yukawa potential. **(04)**

b. i. In the case of partial wave analysis for elastic scattering, derive optical theorem. **(05)**

ii. In an elastic collision between two particles of equal mass, show that the two particles come out at right angles with respect to each other in the Lab frame. **(04)**

c. i. Derive asymptotic form of total scattered wave function in the case of elastic scattering. **(05)**

ii. Show that $\dfrac{d\sigma}{d\Omega} = |f(\theta, \varphi)|^2$. **(04)**

Q. 3. Attempt any two questions out of the (a), (b) and (c) below.

a. i. Discuss Dirac's relativistic Hamiltonian in detail. **(05)**

ii. Derive Klein Gordon wave equation for free relativistic particle. **(04)**

b. i. Derive plane wave solution of Klein Gordon wave equation for free relativistic particle. **(05)**

ii. Prove that Dirac matrices α_x, α_y, α_z and β are traceless and having ± 1 eigenvalues. **(04)**

c. i. Derive continuity equation and expectation values for Dirac's relativistic equation. **(05)**

ii. Obtain the s-wave eigenfunctions of the Klein-Gordon equation for a particle in the square well potential in three dimensions: **(04)**

$$V(r) = \begin{cases} -V_0, & r < a \\ 0, & r > a \end{cases}$$

Q. 4. Attempt any two questions out of the (a), (b) and (c) below.

a. i. Explain significance of negative energy states. **(04)**

ii. Find $[H_D, L_Z]$. **(04)**

b. i. Derive necessary equations for Dirac particle in electromagnetic fields. **(04)**

ii. Show that for a free Dirac particle having momentum $\boldsymbol{p}$, the operator $\boldsymbol{S \cdot p}$ commutes with the Hamiltonian operator $\boldsymbol{H}$. **(04)**

c. i. Derive the necessary equations for relativistic electron in a central Potential. **(04)**

ii. Write a note on: Radial wave equations in coulomb potential. **(04)**

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