St. Philomena's College (Autonomous), Mysore
Question Bank
Programme: M. Sc. Physics
IV Semester
Course Title: QUANTUM MECHANICS-II-HC
Course Type: Hard Core
Q.P Code: 58301

4 Marks Questions

1. Using Born's approximation: Discuss low energy soft sphere scattering.
2. Using Born's approximation: Rutherford scattering.
3. For the case of hard sphere scattering, obtain the expression for scattering angle as a function of impact parameter.
4. For the case of hard sphere scattering, show that differential cross-section is independent of scattering angle.

5 Marks Questions

1. In Rutherford scattering an incident particle of charge q_1 and kinetic energy E scatters off a heavy stationary particle of charge q_2: Determine the differential scattering cross section.
2. In Rutherford scattering an incident particle of charge q_1 and kinetic energy E scatters off a heavy stationary particle of charge q_2: Show that total cross-section for Rutherford scattering is infinite.

6 Marks Questions

1. Describe the underlying principle of Born-Oppenheimer approximation method.
2. State Adiabatic theorem. Explain Adiabatic variation with examples.
3. Write a note on non-holonomic processess.
4. Describe quantum scattering theory and show that differential cross-section is equal to square of the scattering amplitude.
5. Discuss the first Born's approximation and obtain the expression for scattering amplitude at low energy.
6. Discuss the reasons for which Schrodinger equation and Klein Gordon equation of a particle fell into disgrace with the special theory of relativity.
7. Obtain the covarient form of Dirac's equation in terms of γ matrices.
8. Evaluate $(\sigma \cdot A)(\sigma \cdot B)$.
9. Normalize the plane wave solutions of the Dirac equation.
10. "Klein gordon equation represents a system of bosons whereas Dirac equation represents a system of fermions". Justify this statement giving theoretical reasons.

8 Marks Questions

1. Discuss the time dependent perturbation theory and hence deduce Fermi's Golden rule.

2. Discuss the emission and absorption of radiation in the dipole approximation.
3. In Rutherford scattering an incident particle of charge q_1 and kinetic energy E scatters off a heavy stationary particle of charge q_2: Derive the formula relating impact parameter to the scattering angle.
4. Using the strategy of partial analysis: In the case of low energy scattering from a spherical delta function shell $V(r) = \alpha\delta(r - a)$, where α and a are constants, calculate the scattering amplitude $f(\theta)$.
5. Discuss the non relativistic limit of the Klein Gordon Equation.
6. Give the significance of negative energy states and hence explain the concept of antiparticles.
7. Discuss the Hydrogen energy spectra acording to Dirac's theory.

9 Marks Questions

1. Discuss time dependent perturbation theory for two level systems and obtain an expression for probability amplitudes at first and second order.
2. Obtain an expression for the probability of transition of a particle from state a to state b when the perturbation is sinusoidal in nature.
3. Develop time-dependent perturbation theory for a two-level system.
4. Determine the zeroth, first and second order corrections for time dependent perturbation theory.
5. Derive Einstein's co-efficients for spontaneous and stimulated emissions.
6. Discuss selection rules for transitions from an excited state.
7. State and prove Adiabatic theorem.
8. For a non-holonomic system, show that net geometric phase change is a line integral around a closed loop in parameter space.
9. Write short notes on classical and relativistic collisions.
10. Calculate the threshold energy for the reaction $p + p \to p + p + p + \bar{p}$ where a high energy proton strikes a proton at rest, creating a proton-antiproton pair.

10 Marks Questions

1. Show that the transition rate for stimulated emission from state b to state a for a two level system which is under the influence of incoherent, unpolarised light incident from all direction is $R_{a\to b} = \frac{\pi}{3\epsilon_0\hbar^2}|p|^2\rho_0$.
2. Deduce an expression for the life time of an excited state and hence discuss selection rules for transitions from an excited state.
3. Describe classical scattering theory and obtain the expression for differential cross-section.
4. Using the strategy of partial analysis: Discuss the case of hard sphere scattering and show that scattering cross-section is four times the geometrical cross-section, in the low energy approximation.

5. Write down the Dirac's equation in an external electromagnetic field and deduce that the dirac electron has a magnetic moment $\frac{e\hbar\vec{\sigma'}}{2mc}$.

6. Obtain the plane wave solutions to the Klein -Gordon equation.

7. Discuss the scattering of a particle by Yukawa potential.

8. Derive the plane wave solutions to Dirac equation for a free particle.

12 Marks Questions

1. Discuss the formalism of partial wave analysis and obtain the expression for total cross-section.

2. Obtain the integral form of Schridinger equation.

3. Set up the Klein -Gordon equation for a free particle. Obtain the equation of continuity and hence define the probability and current densities.

4. Derive the Dirac equation for a free particle and show that it decomposes into a set of four differential equations and that spin is a natural conscequence in the wave equation.

5. Solve the Dirac equation for a particle in a central field force and calculate the spin orbit coupling energy.

6. Show that the orbital angular momentum operator $\vec{L}$ of a free Dirac particle is not a constant of motion. Describe how the addition of an appropriate spin operator $\vec{S}$ to $\vec{L}$ makes the sum $J = L + S$, a constant of motion.

7. Discuss the Lagrangian formulation for a classical field and arrive at the Euler Lagrange Equation.