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Sardar Patel University

M Sc. (3rd Sem) Examination 2018
Sub: Advanced Quantum mechanics PS03CPHY21
Day and Date: Monday 22 October 2018

Time: 2:00 to 5:00 pm Max. Marks: 70

I Choose the best possible answer from the multiple choices given below each question. [8]

1. The radially outgoing spherical wave is generally represented as

   A) $e^{ikr}.\pi r^2$ B) $\frac{e^{ikr}}{r}$

   C) $e^{-kr}.\pi r^2$ D) $e^{+kr}.\pi r^3$

2. The differential cross section corresponds to the s-wave scattering is given by

   A) $k^2 sin\delta_0$ B) $k^2 tan\delta_0$

   C) $\frac{sin^2\delta_0}{k^2}$ D) $\frac{sin\ \ \delta_0}{k^2}$

3. For a repulsive potential scattering, the partial phase shift becomes

   A) zero B) negative

   C) positive D) infinity

4. In the case of time dependent harmonic perturbation theory, $\omega_{kn} - \omega = 0$ corresponds to

   A) Induced absorption B) Induced emission

   C) Spontaneous emission D) Resonance absorption

5. Identify the transition given below which is dipole allowed.

   A) $1S \to 2S$ B) $2S \to 1d$

   C) $1f \to 3P$ D) $1S \to 2P$

6. The components of Dirac operator **α** satisfy

   A) Poisson bracket relationships B) Commutation relationships

   C) Anticommutation relationships D) None of the above

7. The WKB method for solving a quantum mechanical tunnelling phenomenon is a

   A) relativistic method B) pure quantum calculation

   C) field theoretical approach D) semi classical approach

8. An operator in the Schröedinger picture is transformed to that in Heisenberg picture as

   A) $A_H(t) = V^{-1}(t,t_0)\ A\ (t)\ V(t,t_0)$ B) $A_H(t) = V(t,t_0)\ A\ (t)$

   C) $A_H(t) = V^{-1}(t,t_0)\ A\ (t)$ D) $A_H(t) = i\hbar\ A\ (t)$

(P.T.O.)

II. Short answer questions (attempt any seven. 2x7) [14]

1 Show that the differential cross section is equal to the square of the modulus of the scattering amplitude.
2 Show that the differential cross section (DCS) and the total cross section (TCS) in the case of s-wave scattering are independent of the scattering angle.
3 Derive an expression for the first order perturbed wave function in the case of time independent perturbation theory.
4 Discuss the classical turning points in the case of WKB method.
5 What is the dipole approximation? Explain briefly.
6 Express the Dirac equation in spinor form.
7 Explain the essential features of the interaction picture and its advantage over the other two methods.
8 Explain Einstein's A and B coefficients.
9 Discuss how the negative energy solutions of the Dirac equation are interpreted.

IIIA. Using Born approximation, obtain an expression for the scattering amplitude and discuss the validity of Born approximation. [6]

B. State and prove the Optical theorem in the case of scattering. [6]

OR

B. Derive an expression for the s-wave scattering phase shift in the case of an attractive square well potential [6]

IVA. Compute the first order correction to the ground state energy of a particle of mass, m subjected to a potential $V(x) = \frac{1}{2}m\omega^2x^2 + bx^4$ using the time independent perturbation theory. [6]

B. Obtain the energy Eigen values of harmonic oscillator using WKB method. [6]

OR

B. Using variational method estimate the ground state energy of Helium atom. [6]

VA. A system is subjected to a perturbation H`(t) at an instant, *t*. Calculate the transition probability that has occurred due to this from state *n* to state *k*. [6]

B. Obtain the selection rule for the electric dipole transition in the case of linear harmonic oscillator. [6]

OR

B. Illustrate the differences between the Schrödinger picture and the Heisenberg picture of the quantum dynamics by considering the problem of linear harmonic oscillator Hamiltonian.[6]

VIA. Write down the Dirac equation and solve it for a free spin half particle. [6]

B. Derive the Klein-Gordon equation and derive an expression for the probability density. Discuss the result and show that this equation cannot be used for the description of a relativistic single particle. [6]

OR

B. Show how the spin angular momentum of the electron automatically evolved from Dirac's Hamiltonian. [6]

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