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Third Semester M.Sc. Degree Examination, January 2023

Physics

PH.231 : ADVANCED QUANTUM MECHANICS

(2020 Admission onwards)

Time : 3 Hours | Max. Marks : 75

PART – A

(Answer **any five** questions. Each carries 3 marks)

1. State and prove the Hellman-Feynman theorem.

2. Examine the condition for the validity of the WKB method.

3. Write down the expression for the transition probability in the dipole approximation, for an electron in an atom placed in a radiation field. For which range of wavelengths of this approximation valid? What kind of emission/absorption of radiation can take place at wavelengths for which the dipole approximation is not valid?

4. Show that the eigen values of the parity operator are ± 1. Which of the four fundamental interactions does not conserve parity? Give one example of a parity non-conserving process.

5. Elucidate the relation between the scattering amplitude and the differential scattering cross section for scattering by a spherically symmetric potential.

6. Determine the eigen values of the particle exchange operator for a two particle system. State the generalized principle of indistinguishability.

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7. Explain why the operators J_+ and J_- are called ladder operators.

8. How does the relativistic equation for a charge in a Coloumb field, obtained starting from the relativistic relation between energy and momentum for a free particle, lead to an explanation for the width of the various lines of the hydrogen spectrum?

(5 × 3 = 15 Marks)

PART – B

(Answer **all** questions – each carries **15** marks)

9. (a) Examine the ground state of the helium atom using the variational method and

(b) Hence obtain an estimate for the effective charge of its nucleus as seen by the electrons.

OR

10. (a) Obtain the first order correction to the energy eigen value of the ground state of the helium atom.

(b) Explain Einstein's coefficients.

11. (a) In the first Born approximation determine the scattering cross section for scattering, by a screened coloumb potential.

(b) Explain scattering amplitude and scattering length.

OR

12. (a) Derive the dimensionless Thomas-Fermi equation for a many electron atom in the central field approximation.

(b) Discuss the boundary conditions on the function $\chi(r)$ where the central potential $V(r) = \frac{-Ze^2}{\gamma}\chi(r)$.

13. (a) Using the complete set of orthonormal basis vectors $|jm\rangle$ generate the relevant portion of the matrix operators for the operators J^z and J_z for $j = 0, \frac{1}{2}, 1$.

(b) Explain Pauli spin matrices.

OR

14. (a) Obtain the energy eigenvalues and eigenfunctions for a free spin half particle using Dirac's approach.

(b) Explain negative energy states.

(3 × 15 = 45 Marks)

PART C

Answer **any three** questions – each carries **5** marks.

15. A particle is confined to move along the x axis such that $\psi(x) \to 0$ as $x \to 0, \infty$. It is moving in the potential $V(x) = mg\,x$. For the trial function xe^{-ax} determine the value of that minimizes $\langle H \rangle$.

16. Obtain the relation rule on the magnetic quantum number for transitions of the electron in a hydrogenic atom placed in a plane polarized radiation field with polarization in the xy plane.

17. Obtain an expression for the operator for infinitesimal space translations. Hence illustrate that for an isolated system, invariance of the Hamiltonian under space translation calls for the conservation of linear momentum.

18: In the context of low energy scattering by an attractive square well potential, given the relation $\tan\theta_0 = \left[ka\frac{\tan(k, a)}{k, a} - 1\right]$, where k is the relevant energy multiplied by twice the relevant mass and divided by $\hbar^2$ between the phase shift, the length scale of the potential well, examine the occurrence of the phenomenon of resonance.

19: Prove the unitarily of the Clebsh-Gordan coefficients starting from the raw form of the Dirac equation obtain its convariant form.

20: Explain S-wave scattering by a hard sphere.

(3 × 5 = 15 Marks)
