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Dr. AK

Reg. No. | | | | | | | | | | |

Make up

Manipal University, Manipal
Second Semester M.Sc.(Physics)
End Semester Examination, May 2016
Subject: Quantum Mechanics II (PHY-606)
(Credit System)

Time: 3 hours   Marks: 50

Answer any five full questions.

1. (i) If the eigenvalues of J^2 and J_z are given by $J^2|\lambda, m>= \lambda|\lambda, m>$ and $J_z|\lambda, m>= m|\lambda, m>$. For the simultaneous eigenvector of J^2 and J_z, $|\lambda, m>$ show $\lambda \geq m^2$. Take $\hbar = 1$. [3]
(ii) Show that $\vec{L} \times \vec{L} = i\vec{L}$. [4]
(iii) Determine the orbital momenta of two electrons in the configuration p^1d^1. [3]

2. (i) Calculate the energy correction due to spin-orbit coupling for hydrogen atom. [5]
(ii) Given the matrix for H^0 and H' as $\begin{pmatrix} E_0 & 0 \\ 0 & E_0 \end{pmatrix}$ $\begin{pmatrix} 0 & -A \\ -A & 0 \end{pmatrix}$ in the orthonormal basis $|1>$ and $|2>$, determine the
(a) energy eigenvalues [2]
and (b) energy eigenfunctions. [3]

3. (i) Using WKB method calculate the expressions of wavefunctions in classical region. [4]
(ii) Write the Hamiltonian for a Helium atom. [2]
(iii) Estimate the ground state energy for a Helium atom using the variational method with the trial wavefunction

$$\psi_{tr} = \frac{8}{\pi a^3} exp\left(-\frac{2(r_1 + r_2)}{a}\right) \qquad [4]$$

4. (i) Obtain expression of transition probability for a time dependent harmonic perturbation. [5]
(ii) Calculate the Einstein B coefficient for the n=2, l=1, m=0, $\to$ n=1, l=0, m=0 transition in the hydrogen atom. [5]

5. (i) Discuss the phase shift technique used to study the quantum scattering process. [5]
(ii) In a scattering experiment, the potential is spherically symmetric and the particles are scattered at such energy that only s

and p waves need to be considered.

(a) Show that the differential cross-section $\sigma(\theta)$ can be written in the form $\sigma(\theta) = a + b cos\theta + c cos^2\theta$. [2]

(b) What are the values of a, b, and c in terms of phase shifts? [3]

6. (i) Using the Klein-Gordon equation show that the expressions for relativistic and non-relativistic position probability densities are different. [3]

(ii) Obtain different anticommutation relations with the help of Dirac Hamiltonian. [3]

(iii) Prove that the operator $c\vec{\alpha}$, where $\vec{\alpha}$ stands for Dirac matrices, can be interpreted as the velocity operator. [4]

Useful formulae:

$$\nabla^2 t = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial t}{\partial r}\right) + \frac{1}{r^2 sin\theta}\frac{\partial}{\partial\theta}\left(sin\theta\frac{\partial t}{\partial\theta}\right) + \frac{1}{r^2 sin^2\theta}\frac{\partial^2 t}{\partial\phi^2}$$

$$\psi_{210} = \left(\frac{1}{32\pi a^3}\right)^{\frac{1}{2}}\frac{r}{a}exp\left(-\frac{r}{2a}\right)cos\theta$$

$$\psi_{100} = \left(\frac{1}{\pi a^3}\right)^{\frac{1}{2}} exp\left(-\frac{r}{a}\right)$$

$$\int_0^\infty x^n exp(-ax)\, dx = \frac{n!}{a^{n+1}}, \quad n \geq 0, a > 0$$