M.Sc.(Physics) (CBCS Pattern) Semester - III

PSCPHYT09 - Core Paper-IX : Quantum Mechanics-II

P. Pages : 2 **GUG/S/23/11295**

Time : Three Hours * 1 4 6 4 * Max. Marks : 80

Either

1. a) Give first order perturbation theory of non-degenerate system and find the expression of energy. **6**

b) Consider the infinite square well defined by $v(x) = 0$ for $0 \le x \le a$ and $v(x) = \infty$ otherwise. Using first order perturbation theory, calculate the energy of the first two states of the potential well if a portion defined by $v(x) = \frac{v_0 x}{a}$ v_0 = constant, $0 \le x \le a$ is sliced off. **4**

c) Explain the application of perturbation theory to ground state energy of the He-atom. **6**

OR

e) Define stark effect. Explain first order stark effect in the ground and first excited state of H-atom. **8**

f) Explain normal and anomalous Zeeman effect. **6**

g) Explain the splitting of $^1P \rightarrow {}^1S$ transition of an atom placed in a magnetic field B along Z-axis. **2**

Either

2. a) Explain use of WKB method in barrier penetration. **6**

b) Derive the ground state energy of He-atom using variational principle. **6**

c) Estimate the ground state energy of a one-dimensional harmonic oscillator of mass 'm' and angular frequency $'\omega'$ using a Gaussian trial function $\phi(x) = A\exp(-\alpha r^2)$. **4**

OR

e) Discuss time dependent perturbation theory. **6**

f) A system in an unperturbed state n is suddenly subjected to a constant perturbation H'(r) which exists during time $0 \rightarrow t$. Find the probability for transition from state n to state k and show that it varies simple harmonically with angular frequency = $\frac{E_k - E_n}{2\hbar}$ and Amplitude = $4\frac{|H'_{kn}|^2}{(E_k - E_n)^2}$. **4**

g) Derive the relation between absorption and induced emission on the basis of time-dependent perturbation theory. **6**

Either

3. a) Explain Born-Oppenheimer approximation in scattering. **6**

b) Discuss scattering cross-section in laboratory and centre of mass system. **6**

c) In a scattering experiment, the potential is spherically symmetric and the particles are scattered at such energy that only S & P wave need be considered : **4**

i) Show that, the differential cross section $\sigma(\theta)$ can be written in the form

$$\sigma(\theta) = a + b\cos\theta + c\cos^2\theta$$

ii) What are the values of a, b, c in terms of phase shifts.

OR

e) Derive the expression of wavefunction and energy of the ortho and para states of the He-atom and their perturbation by coulomb repulsion. **8**

f) Explain the Heitler-London theory of H-molecule. **6**

g) N non-interacting bosons are in an infinite potential well defined by $v(x) = 0$ for $0 < x < a$; $v(x) = \infty$ for $x < 0$ and for $x > a$. Find the ground state energy of the system. What would be the ground state energy if the particles are fermions. **2**

Either

4. a) Derive Kelvin-Gordon equation for a free particle. **6**

b) Show that the following matrices form a representation of Dirac's matrices. **2**

$$\alpha_x = \begin{pmatrix} \sigma_x & 0 \\ 0 & -\sigma_x \end{pmatrix}, \alpha_y = \begin{pmatrix} 0 & I \\ I & 0 \end{pmatrix}, \alpha_z = \begin{pmatrix} \sigma_z & 0 \\ 0 & -\sigma_z \end{pmatrix} \quad \beta = \begin{pmatrix} 0 & iI \\ -iI & 0 \end{pmatrix}$$

c) For a relativistic electron in central potential, show that the spin-orbit interaction comes out automatically from Dirac's equation. **8**

OR

e) Prove that, a Dirac electron has a magnetic moment $\mu = \dfrac{e\hbar\sigma}{2mc}$ **6**

f) Discuss the solution for H-atom in Dirac theory. **8**

g) Prove that, the operation $c\alpha$, where α stands for Dirac matrix, can be interpreted as the velocity operator. **2**

5. Attempt **all** the following:

a) Calculate the 1st order energy correction for an harmonic oscillator. **4**

b) Explain Dipole approximation. **4**

c) Interprete the concept of Identical particles. What is difference between Boson and Fermions. **4**

d) Give physical significance of negative energy states. **4**

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