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(A-103)

SARDAR PATEL UNIVERSITY
M. Sc. Physics III[rd] Semester Examination
Tuesday, Date: 21-04-2015 Time: 02.30 P.M. to 05.30 P.M.
Course No. CBCS: PS03CPHY01
Subject: Quantum Mechanics–II

Note: Symbols have their usual meaning. **Total Marks: 70**

Q.1 Write answers of all eight questions in a table form by showing your choice Against the question number. **(8)**

(1) The co-ordinate representation of time evolution operator in *interaction* picture leads to _______ .
(a) Dirac matrix mechanics (b) Schrödinger representation
(c) uncertainty principle (d) Feynman diagram

(2) General criterion to apply Born approximation is _______ .
(a) K.E. << V(r) (b) K.E. = V(r) (c) K.E. >> V(r) (d) K.E. = 0

(3) For Pauli matrices; $[\sigma_x, \sigma_y]$ = _____. Take $\hbar = 1$.
(a) $-i\sigma_z$ (b) $-i\sigma_+$ (c) $i\sigma_+$ (d) $i\sigma_z$

(4) Unit of Einstein coefficient A is _______.
(a) sec (b) sec^{-1} (c) sec^2 (d) J/sec

(5) In the matrix representation of angular momentum $j = ½$, J_+ = _____. Take $\hbar = 1$.
(a) $\begin{pmatrix}0 & 1\\0 & 1\end{pmatrix}$ (b) $\begin{pmatrix}0 & 1\\1 & 0\end{pmatrix}$ (c) $\begin{pmatrix}0 & 0\\0 & 1\end{pmatrix}$ (d) $\begin{pmatrix}0 & 1\\0 & 0\end{pmatrix}$

(6) $\left[i\hbar\frac{\partial}{\partial t} - H(t)\right] G_R(\mathbf{r},\mathbf{r}';t,t')$ = _______ .
(a) $\delta(\mathbf{r}-\mathbf{r}')$ (b) $\delta(\mathbf{r}-\mathbf{r}')\,\delta(t-t')$ (c) $\delta(\mathbf{r}-\mathbf{r}')/\delta(t-t')$ (d) $\delta(t-t')$

(7) The radial momentum operator is given by _______.
(a) $\frac{(\mathbf{r}.\mathbf{p} - i\hbar)}{r}$ (b) $\mathbf{r}.\mathbf{p} - i\hbar$ (c) $\mathbf{r}.\mathbf{p}$ (d) $\mathbf{r}.\mathbf{p} + \frac{i\hbar}{r}$

(8) Which of the following transition is electric dipole allowed?
(a) $1s \rightarrow 2s$ (b) $2p \rightarrow 3d$ (c) $3s \rightarrow 4f$ (d) $3s \rightarrow 5d$

Q.2 Answer any seven questions. **(14)**

(1) What are *spinors*? Write their one property.
(2) If two operators **A** and **B** commute with spin matrix **σ**, then prove that $(\boldsymbol{\sigma}.\mathbf{A})(\boldsymbol{\sigma}.\mathbf{B}) = \mathbf{A}.\mathbf{B} + i\boldsymbol{\sigma}(\mathbf{A}\times\mathbf{B})$.
(3) Prove that $c\boldsymbol{\alpha}$ can be interpreted as the velocity operator. Here, $\boldsymbol{\alpha}$ stands for Dirac matrix and c is the speed of light in vacuum.
(4) Using time dependent Schrödinger equation, deduce the integral form for propagator.
(5) What is meant by 'dipole approximation'? When is it a good approximation?
(6) Write the difference between classical and quantum *Liouville* equation.

(7) Prove that $|\vec{J}|^2 = J_-J_+ + \hbar j_z + j_z^2$.

(8) What are *Clebsch-Gordan* coefficients? Write their one importance.

(9) Obtain the value of $[j_z, J_+]$.

Q.3 **(a)** For the ladder operator J_+, obtain the expression for normalization constant $c_{j,m}^{+}$. Obtain matrix representation for operators J^2 and j_z in the $|\lambda, m\rangle$ basis. **(6)**

(b) Assuming $[S^2, s_z] = 0$, expand any spin state $|\chi\rangle$ in terms of complete ortho- -normal eigenstates $|s, m_s\rangle$. As a special case, write spin wave functions for $s = \frac{1}{2}$. Write total wave function for it, and interpret each term in it. **(6)**

OR

(b) Derive an expression for non-relativistic Hamiltonian including spin. Explain each term of it, and write an expression for corresponding energy eigenvalues. **(6)**

Q.4 **(a)** Write detailed note on Density Matrix and its usefulness. **(6)**

(b) What is *propagator*? Obtain its differential form. Derive an expression for transition amplitude (c_{fi}) within the *sudden* approximation. **(6)**

OR

(b) "Electromagnetic waves behave as Harmonic oscillator" – Prove this state- -ment with necessary equations. Discuss its quantization. **(6)**

Q.5 **(a)** Write down the Dirac equation for a single particle of mass m and derive the properties of the Dirac matrices. **(6)**

(b) For free Dirac particle, obtain the positive and negative energy solutions. Explain these solutions. **(6)**

OR

(b) Starting with a suitable Lagrangian density for Klein–Gordon field, express the Hamiltonian in terms of the number operators corresponding to positive and negative energies. **(6)**

Q.6 **(a)** Write detailed note on Schrödinger picture for time evolution of quantum mechanical system. Give difference between Schrödinger picture and Heisenberg picture. **(6)**

(b) Write note on addition of angular momenta. Discuss the phase convention while determining the CG coefficients. **(6)**

OR

(b) Derive an expression for probability density in the case of a Dirac particle and show that it has the same form as in the case of a non-relativistic expression resulting into a positive definite value. **(6)**

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