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SEAT No.________

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SARDAR PATEL UNIVERSITY
M. Sc. Physics IIIrd– Semester Examination
Tuesday, 19th March 2019 Time: 10:00 a.m. to 1:00 p.m.
Course No: PS03CPHY01
Subject: Quantum Mechanics -II

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

Q.1 Select the best possible answer from the choices given below each questions. (8)

(1) If the quantum mechanical operator satisfies the relation $\hat{A} = \hat{A}^{\dagger}$ then $\hat{A}$ is a
(a) Hermitian operator (b) self adjoint operator
(c) Projection operator (d) Unitary operator

(2) The Process of solving the eigenvalue problem for an operator can often referred to as
(a) Diagonalization of the operator (b) Normalization of the operator
(c) Transformation of the operator (d) degeneracy of the operator

(3) The commutator operator between the angular momentum operators $[J_+, J_-]$ is given by
(a) $\hbar J_+$ (b) $\hbar J_-$
(c) $\hbar J_z$ (d) $\hbar J_x$

(4) The allowed quantum transitions must respect the ________.
(a) dipole selection rules (b) Cauchy rules
(c) Angular momentum commutator rules (d) Quadrupole selection rules

(5) If there is no exchange of energy between the colliding objects as seen from their center of mass frame then the collision is said to be
(a) inelastic (b) Super inelastic
(c) not occurred (d) elastic

(6) The operator A_H in the Heisenberg picture is related to that in Schrödinger picture as
(a) $V^{-1}(t, t_0)A(t)V(t, t_0)$ (b) $V^{-1}(t, t_0)A(t)$
(c) $A(t)V(t, t_0)$ (d) $V^{\dagger}(t, t_0)A(t)V(t, t_0)$

(7) The probability current density for a Dirac particle is expressed as
(a) $c\psi^{\dagger}\beta\,\psi$ (b) $c\psi^{\dagger}\,\psi$
(c) $c\psi^{\dagger}\alpha\,\psi$ (d) $\psi^{\dagger}\beta\,\psi$

(8) For the Harmonic oscillator annihilation operator, a, the commutator $[H, a]$ becomes
(a) a (b) $-\hbar a$
(c) $\hbar a^{\dagger}$ (d) $a^{\dagger}$

(P.T.O.)

Q.2 Answer any seven questions. All questions carry 2 marks each (7x2=14)

(1) Write the matrix representation of angular momentum operators.
(2) Define the Clebsch - Gordan coefficient.
(3) Explain sudden approximation in the case of time dependent Schrödinger equation.
(4) Show that the Pauli spin matrices satisfies the commutation relation, $[\sigma_x, \sigma_y] = 2i\,\sigma_z$
(5) Express the Fermi – Golden rule mathematically and explain its importance.
(6) Discuss briefly about the Harmonic perturbation.
(7) Explain how the negative energy solutions are interpreted in Dirac's theory.
(8) Argue how the concept of spin automatically comes out in Dirac theory.
(9) What is second quantization? Why it is called so?

Q.3(a) Define angular momentum raising and lowering operators and compute the matrix representations of $\langle j'm'|J_{\pm}|jm\rangle$. (6)

(b) The vector **J** represents the sum of angular momenta, **j₁** and **j₂**. Prove that the components of **J** satisfy the usual angular momentum commutation relations. (6)

OR

(b) Compute the Clebsh-Gordan Coefficients for the addition of angular momentum of two particles having their angular momentum $j_1 = 1$ and $j_2 = \frac{1}{2}$ (6)

Q.4(a) Obtain the selection rules for electric dipole transitions of a linear harmonic oscillator. (6)

(b) Define density matrix and discuss its properties. Obtain the spin density matrix. (6)

OR

(b) Discuss in detail the interaction of an atom with quanta of electromagnetic radiation. (6)

Q.5(a) Outline the differences between Heisenberg and Schrödinger picture and discuss the interaction picture. (6)

(b) Discuss in detail the Dirac's Hamiltonian and explain the propertiesof the Dirac's matrices. Express these matrices in terms of the Pauli matrix. (6)

OR

(b) Obtain the Klein- Gordon equation as relativistic generalization of Schrödinger equation and discuss its plane wave solution. (6)

Q.6(a) Discuss the harmonic oscillator problem using creation and annihilation operators. Express the Hamiltonian in terms of the number operator. (6)

(b) Describe the second quantization procedure by taking the case of a system of bosons. (6)

OR

(b) For a system of Fermions, define the number operator and show that its eigen values are zero or one. (6)

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