[206/A45] SEAT No.________ No. of Printed Pages : 3

SARDAR PATEL UNIVERSITY

M. Sc. (Physics) 3rd Semester Examination
Monday, 22nd October, 2018
Time: 02:00 pm to 05:00 pm
Subject: PS03CPHY01 [Quantum Mechanics-II]

Total Marks: 70

Note: (1) Figures to the right indicate marks.
(2) Symbols have their traditional meaning.

Q:1 **Attempt all of the following Multiple choice type questions. [01 mark each]** [08]

(1) For Pauli matrices $\sigma_{-}\sigma_{+} =$ _____.

(a) $2(1-\sigma_z)$
(b) 0
(c) $2(1+\sigma_z)$
(d) 1

(2) $(J_{+} + J_{-}) =$

(a) 2 Jz
(b) 0
(c) 2 Jx
(d) 2 Jy

(3) The quantum Liouville equation is given as

(a) $i\hbar \frac{d\hat{\rho}}{dt} = [\hat{H}, \hat{\rho}]$
(b) $\frac{d\hat{\rho}}{dt} = [\hat{H}, \hat{\rho}]$
(c) $i\hbar \frac{d\hat{\rho}}{dt} = \hat{H}\hat{\rho}$
(d) $i\hbar \frac{d\hat{\rho}}{dt} = Tr(\rho^2)$

(4) The dipole approximation is given by

(a) $\nabla \cdot A = 1$
(b) $\nabla \cdot A = 0$
(c) $\exp(i\vec{k}\cdot\vec{r}) \approx 1$
(d) $\exp(i\vec{k}\cdot\vec{r}) \approx 0$

(5) The energy spectrum of a free Dirac particle consists of

(a) Dirac particles.
(b) two branches.
(c) four branches.
(d) one branch.

(6) The Pauli spin matrix $\sigma_z =$

(a) $\begin{pmatrix} 0 & i \\ i & 0 \end{pmatrix}$
(b) $\begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$
(c) $\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$
(d) $\begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}$

(7) In Natural units ($\hbar = c = 1$), dimensional formula for electric charge is _______.

(a) $M^1L^0T^0$
(b) $M^1L^1T^0$
(c) $M^1L^0T^{-1}$
(d) $M^0L^0T^0$

(P.T.O.)

(8) Klein-Gordon field corresponding to spin $s =$ ______ .

(a) 1/2 (c) 5/2

(b) 3/2 (d) 0

Q:2 **Answer any 7 of the following 9 questions briefly. [02 marks each]** [14]

1. Define Clebsh-Gorden coefficients.
2. Explain phase convention.
3. Define hármonic and constant perturbation.
4. Explain propagator.
5. Describe the scattering operator.
6. What is the drawback of the Klein-Gorden equation. Write Dirac's relativistic Hamiltonian.
7. Explain Schrödinger picture.
8. Define field. Write its coordinate.
9. Give $\hat{a}$ and $\hat{a}^{\dagger}$ operators in terms of position and linear momentum operators. Prove that $\left[\hat{a}^{\dagger}, \hat{a}\right] = -1$.

Q:3 (a) Obtain the eigen value spectrum and J^2 and J_z. [6]

(b) Write down the Pauli spin matrices and describe their properties. Show that $(\vec{\sigma}\cdot\vec{r})(\vec{\sigma}\cdot\vec{p}) = \vec{r}\cdot\vec{p} + i\vec{\sigma}\cdot\vec{L}$ [6]

OR

(b) Discuss the coupling of two spin-1/2 particles and obtain the spin wave function corresponding to the singlet and triplet states. [6]

Q:4 (a) Obtain the general solution of time-dependent Schrödinger equation. [6]

(b) Considering elastic scattering of a particle by a potential, derive expression for probability per unit of scattering and differential scattering cross-section. [6]

OR

(b) Using time dependent perturbation theory, deduce solution for transition amplitude and establish Fermi's golden rule. [6]

Q:5 (a) Show that the plane wave solution of the equation gives $E = \pm(c^2\vec{p}^2 + m^2c^4)^{1/2}$. Interpret these solutions for the relativistic wave equation in terms of $P(\vec{x},t)$ and $S(\vec{x},t)$. [6]

(b) Write a note on Heisenberg picture. [6]

OR

(b) Obtain the plane wave solutions of the Dirac equation. [6]

Q:6 (a) Derive the Lagrangian classical field equation. Deduce the classical field equation analogous to Langrange's equation for a system of particles. [6]

(b) Derive Hamiltonian form of field equation. For a dynamical physical quantity F as a functional of ψ and Π, obtain its time rate of change and introduce the definition of Poisson bracket for field coordinates. [6]

OR

(b) Explain *second quantization*? Deduce the time dependent Schrödinger equation, using Hamiltonian form for field equation with Lagrangian density as $£ = i\hbar\psi^*\dot{\psi} - \frac{\hbar^2}{2m}(\nabla\psi^*)(\nabla\psi) - V(\vec{r},t)\psi\psi^*$ [6]

—X—

(3)