M. Sc. Physics Examination, 2023

(2nd Year, 1st Semester)

High Energy Physics

Paper – Sc/PHY/PG/CBS/TH/202/2023

Time : Two hours | Full Marks : 40

Answer any four questions (4×10).

1. Write down the Dirac equation in covariant form.

   Then, transform the equation and express it in terms of an adjoint spinor $\bar{\psi} = \psi^\dagger \gamma^0$.

   Derive a continuity equation from this equation. Discuss the physical interpretation of this conserved current.

2. Define $\gamma_5 = i\gamma^0\gamma^1\gamma^2\gamma^3$. Show that $\gamma_5^2 = 1$ and $\{\gamma_5, \gamma^\mu\} = 0$.

   Show further that $P_\pm := \frac{1\pm\gamma_5}{2}$ define projection operators.

   Check further whether the chiral Dirac current $j_5^\mu = i\bar{\psi}\gamma^\mu\gamma_5\psi$ is a conserved current?

3. For a free scalar field, show how the field and the lagrangian transform under parity transformation. Requiring parity invariance show that intrinsic parity for the field is ± 1. Show that for a free photon field, one cannot tell whether the intrinsic parity is positive or negative.

4. Write down the general expression for differential cross section for the process $AB \to CD$.

   For a scattering process of the form $AB \to CD$ define Mandelstam variables. Show that sum of these variables is $m_A^2 + m_B^2 + m_C^2 + m_D^2$.

[Tuen over

5. Write down two examples of decay processes for i) electromagnetic, ii) strong and iii) weak interactions. Are parity, charge conjugation conserved in all three above interactions?

   Draw the Feynman diagram for Moller scattering $e^-e^- \to e^-e^-$.

6. Write down invariant current-current form of the amplitude for β-decay proposed by Fermi. Then write down its correct amplitude. Draw the Feynman diagram for muon decay.

7. Write down how a Dirac field transforms under $U(1)$ local and global transformation. Show that the Lagrangian $L = i\bar{\psi}\gamma^\mu\partial_\mu\psi - m\bar{\psi}\psi$ is invariant under global gauge transformation, but not under local gauge transformation.

   Now explain how a gauge field is introduced by demanding local phase invariance.

8. Write down the Lagrangian of Quantum Electrodynamics (QED).

   Show that addition of a mass term $\frac{1}{2}m^2A_\mu A^\mu$ is prohibited by gauge invariance and the gauge particle, the photon, must be massless.