**8.** *(i)* How are the strong and electroweak interactions classified in Standard Model gauge interactions?

*(ii)* Give example of two-decay processes for strong, electromagnetic and weak interactions and order of magnitudes of their life times indicating the main determining factors.

*(iii)* Make a complete generation wise list of fermion doublets and fermion singlets for standard Model electroweak interactions with their baryon number, lepton number and electric charge. 3+3+4

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**M. Sc. EXAMINATION, 2024**

**(2nd Year, 1st Semester)**

**PHYSICS**

**PAPER : CBS/TH/202**

**( High Energy Physics )**

*Time* : 2 *Hours* *Full Marks* : 40

Answer two questions from each group. $(10 \times 2) + (10 \times 2) = 40$

**GROUP—A**

**1.** Write down the Dirac equation in covariant form and mention the algebra that the Dirac matrices satisfy.
Define the adjoint of a Dirac spinor and derive the equation it satisfies. Derive a continuity equation for the Dirac equation. Discuss the physical interpretation of this conserved current. [3+3+4]

**2.** Define $\gamma_5 = i\gamma^0\gamma^1\gamma^2\gamma^3$. Find the value of $\gamma_5^2$ and $\{\gamma_5, \gamma^\mu\}$.

Show further that $P_\pm := \frac{1 \pm \gamma_5}{2}$ define projection operators. Check under what conditions the chiral Dirac current $j_5^\mu = i\bar{\psi}\gamma^\mu\gamma_5\psi$ is conserved? [4+3+3]

**3.** *(i)* Write down $SU(2)\times U(1)$ gauge invariant Lagrangian for the scalar field.

*(ii)* Then using familiar Higgs potential and appropriate vacuum expectation value calculate the mass terms of the gauge boson fields along with their mass eigen states. 3+7

**4.** *(i)* Write down Fermi's four-fermion current-current interaction term for beta decay.

*(ii)* Show that this interaction is parity conserving.

*(iii)* Then write down parity violating current-current interaction term for beta decay.

*(iv)* Draw the Feynman diagram for beta decay following Standard Model interactions and then write down the invariant amplitude of the decay from the diagram following Feynman's rules. 1+3+2+4

## GROUP—B

**5.** *(i)* Verify that Dirac equation follows from $\mathcal{L} = i\bar{\psi}\gamma_\mu\partial^\mu\psi - m\bar{\psi}\psi$ .

*(ii)* From this Lagrangian develop $U(1)$ local gauge invariant Lagrangian. Write down the kinetic term of the newly introduced gauge field.





*(iii)* Show that the addition of mass term of this gauge field is prohibited by $U(1)$ gauge invariance. 2+5+3

**6.** *(i)* Introduce cross-section of a two-body decay in terms of Feynman amplitude explaining each factors.

*(ii)* Derive the formula for cross-section of a scattering process using the parameters used in the experiments.

*(iii)* Considering above two definitions explain the physical meaning of cross-section. 4+4+2

**7.** *(i)* Write down the plain wave solutions for free scalar field, free Dirac field, and free vector field.

*(ii)* How was it determined that Dirac field represents half integer spin particles? Define a parameter which is measured in experiment to identify the spin of an elementary particle.

*(iii)* Prove that $\left(\vec{\sigma}.\vec{a}\right)\left(\vec{\sigma}.\vec{b}\right) = \vec{a}.\vec{b} + i\vec{\sigma}.\vec{a}\times\vec{b}$

*(iv)* For a scattering process of the form $AB \rightarrow CD$ define Mandelstam variables. Show that sum of these variables is $m_A^2 + m_B^2 + m_C^2 + m_D^2$ . 1.5+2+3+3.5