2024
M.Sc.
4th Semester Examination
PHYSICS
PAPER – PHS-401
Full Marks: 50
Time: 2 Hours

Paper code: 401.1 (Quantum Field Theory)

ANSWER Q1, Q2, AND ANY ONE FROM Q3 AND Q4

1. Answer any two (02) from the following: 2×2=4

(a) State and explain the Noether's theorem of symmetry.
(b) What is more fundamental, fields or particles? Justify your answer.
(c) For free scalar field construct the Hamiltonian density and i-th momentum.
(d) Show that vacuum expectation value of time ordered product of the odd numbers of field operators are vanishes.

2. Answer any two (02) from the following: 2×4=8

a) Define conserved current. Discuss the translational symmetry for free real scalar theory and deduce conserved charge in terms of the field. (1+3)
b) Write down the Lagrangian density of the photon field and hence construct the Hamiltonian and momentum density of the field. (1+3)
c) State the Wick's theorem and prove this for three Fermionic operators. (4)
d) Write down the free Dirac equations and hence construct the Lagrangian density of the Dirac field and check if the Lagrangian is Hermitian. (1+1+2)

3. (a) For a real scalar field with Lagrangian $L = \frac{1}{2}\partial_\mu\phi\partial^\mu\phi - \frac{1}{2}m^2\phi^2$, show that after normal ordering the conserved 4-momentum has the operator form $P^\mu = \int \frac{d^3k}{(2\pi)^3 2E(\mathbf{k})} k^\mu a^\dagger(\boldsymbol{k})a(\boldsymbol{k})$.

(Turn Over)

(b) Construct the Lagrangian density for the free complex scalar field theory. (5+3)

4. (a) Deduce the Feynman propagator for the Dirac field.
(b) For $\lambda\varphi^3$ theory, construct the Hamiltonian density and hence calculate the contribution to the two-point function, showing Feynmann diagrams up to the 2nd order in λ. (5+3)

Paper code: 401.2 (Particle Physics)

ANSWER Q1, Q2, AND ANY ONE FROM Q3 AND Q4

1. **Answer any two (02) of the following:** **2×2=4**

(a) Estimate the ratio of the potentials of electromagnetic and gravitational interaction. Take mass of proton = *1GeV/c²* and $\frac{e^2}{\hbar c} = \frac{1}{137}$, $G_N = 6.7 \times 10^{-39} \hbar c\ (GeV/\ c^2)^{-2}$.

(b) Explain the non-occurrence or occurrence of the following process with proper reasoning:

$$(i)\ \Sigma^+ \rightarrow \pi^0 + \pi^+ \qquad (ii)\ p + p \rightarrow K^+ + K^+ + n + n$$

(c) Differentiate between reducible and irreducible representation of a group.

(d) Draw the Y-I_3 diagram (weight diagram) of the baryon decuplet and also write the baryons in terms of quarks with explanations.

2. **Answer any two (02) of the following:** **2×4=8**

a) Draw and explain the Weight diagram for meson octet *(K, η, π).* (4)
b) What is charge conjugation? Discuss the CPT theorem (Luders-Pauli theorem). (2+2)

c) i) Write Young diagrams of irreducible representation of S_4

ii) Suppose we have a set of transformation $x' = f(x, a)$. Also assume that an identity transformation exists and that the transformations are associative. Write down the requirements so that this transformation forms a Lie group. (2+2)
d) Discuss the origin and resolution of τ-Θ puzzle. (4)

3. (a) Calculate the generators of the SO(3) group.
(b) Discuss what is meant by neutral Kaon oscillation. (4+4)

4. (a) Define Mandelstam variables in $2 \rightarrow 2$ process and show that $s + t + u = \sum_{t=a}^{d} m_i^2 = constant$. (b) What is hypercharge? How it is connected with the multiplet of the group of the respective particle? (c) Write down the SU(2) Lie algebra and show that the generator are traceless. (4+2+2)

(All the symbols have their usual meanings)

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Internal Assessment-10