REV-01
MSP/11/16

2023/06

SET A

M.Sc. PHYSICS
FOURTH SEMESTER
ADVANCED HIGH ENERGY PHYSICS
MSP - 403C
[USE OMR FOR OBJECTIVE PART]

Duration : 3 hrs. **Full Marks : 70**

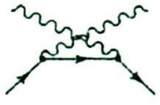
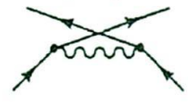
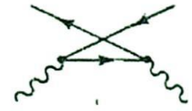
(PART-A: Objective)

Time : 30 min. **Marks : 20**

Choose the correct answer from the following: ***1X20=20***

1. In QED, the process where an electron and a positron annihilate, producing a photon, which then generates a new electron-positron pair is known as
   a. Compton scattering
   b. Bhabha scattering.
   c. Pair production
   d. Pair annihilation.

2. Which of the following represent a spin half incoming positron?
   a. 
   b. 
   c. 
   d. 

3. Which of the following Feynman diagrams represents pair production process?
   a. 
   b. 
   c. 
   d. 

4. According to Feynman rules of quantum electrodynamics massless spin-1 photon propagator is expressed as
   a. $\frac{-i\epsilon_\mu}{p^2}$
   b. $\frac{-ig_{\mu\nu}}{p^2}$
   c. $\frac{-i}{p^2-m^2}$
   d. $-ie\gamma^\mu$

5. Which of the following represents the Callan-Gross relation of proton structure function
   a. $2xF_1(x) = F_2(x)$
   b. $2xF_1(x) = -F_2(x)$
   c. $F_1(x) = F_2(x)$
   d. $F_1(x) = 2xF_2(x)$

6. If $f_i(x)$ denotes the parton momentum distribution then the value of $\sum_i \int x\, f_i(x)dx$ is (where, i is the sum over all the charged and uncharged partons)
   a. 0
   b. 1
   c. 3
   d. 6

7. According to Feynman rules of quantum chromodynamics, which of the following represent an incoming antiquark? (the symbols have their usual meanings)
   a. $\bar{\nu}c$
   b. $\bar{u}c^{\dagger}$
   c. $\bar{\nu}c^{\dagger}$
   d. $\nu c^{\dagger}$

8. Which of the following interaction is not possible?
   a. $s + u \rightarrow W^-$
   b. $e^- \rightarrow \nu_e + W^-$
   c. $e^- \rightarrow \nu_\mu + W^-$
   d. $s + \bar{u} \rightarrow W^-$

9. Which of the following particles initiated the quest for the Higgs boson?
   a. W and Z bosons
   b. up and down quarks
   c. mesons and baryons
   d. neutrinos and photons

10. The proton form factor $F(0) = 1$ at $q \rightarrow 0$. This is true by virtue of
    a. quantization
    b. Polarization
    c. orthogonality
    d. normalization

11. One of the important discoveries that establishes the Weinberg-Salam theory of electroweak interaction involves the discovery of W and Z gauge bosons, the other being the discovery of
    a. neutral currents in neutrino scattering
    b. charged currents in neutrino scattering
    c. neutrino oscillations
    d. spontaneous symmetry breaking

12. Which of the following statements is true?
    a. Strangeness changing process is stronger than strangeness conserving process
    b. Strangeness changing process is weaker than strangeness conserving process
    c. Strangeness changing process is equal in strength as strangeness conserving process
    d. None of these

13. In a semi-leptonic weak decay $\overline{K^0} \rightarrow \pi^+ + ? + \overline{\nu_\mu}$, what is the missing particle?
    a. e^-
    b. μ^-
    c. ν_e
    d. Σ^-

14. The Goldstone boson, appeared in a spontaneously broken Gauge theory, is a
    a. massive gauge boson
    b. massless spin 1 boson
    c. massless spin 0 boson
    d. a spinor

15. The V-A theory of weak interaction is
    a. Parity (P) invariant
    b. charge conjugation (C) invariant
    c. CP invariant
    d. none of the above

16. If the Lagrangian (L) carries unit of energy, and the Lagrangian density ($\mathcal{L}$) carries dimension as

a. $\sqrt{ML}/T$
b. $ML^{-1}T^{-2}$
c. $ML^{2}T^{-2}$
d. $L^{-3/2}$

17. The Grand Unified Theory unifies

a. only strong and electromagnetic force
b. only electromagnetic and weak force
c. only strong, electromagnetic and weak force
d. all strong, electromagnetic, weak and gravitational force

18. String theory suggests that the elementary particles are one-dimensional strings as opposed to zero-dimensional point particles. These strings are of the order of

a. 10^{-35} Å
b. $10^{-35}\ m$
c. $10^{35}\ mm$
d. $10^{-35}\ cm$

19. The group representation of a naive Grand Unified Theory is

a. $\boldsymbol{SU_C(3) \times U(1)}$
b. $\boldsymbol{SU_L(2) \times U(1) \times SU_C(3)}$
c. $\boldsymbol{SU_1(1) \times U_L(2) \times SU_C(3)}$
d. $\boldsymbol{SU_{em}(1) \times SU_C(3)}$

20. According to supersymmetry (SUSY) all fermions should have bosonic partners with different values of

a. mass
b. charge
c. spin
d. parity

-- --- --

(Descriptive)

Time : 2 hrs. 30 mins. **Marks : 50**

[Answer question no.1 & any four (4) from the rest]

1. Using Feynman rules of QED evaluate the differential cross-section of the elastic Mott scattering process ($m_3 = m_1, m_4 = m_2$) in the laboratory frame. **10**

2. **a.** List the Feynman rules of Quantum electrodynamics. **6+4=10**
   b. Draw the lowest-order Feynman diagram for the following processes:
   (a) Bhaba scattering
   (b) Moller scattering

3. Explain thoroughly the process of deep inelastic electron-proton scattering $ep \rightarrow eX$. [Symbols have their usual meaning.] **10**

4. **a.** What do you mean by scaling violations of structure functions in quantum chromodynamics (QCD)? **2+3+5 =10**

   b. Draw the gluon emission diagram which provides jets with $p_T \neq 0$ for the following process in the centre of mass frame $\gamma^* q \rightarrow qg$. Also mention the physical significance of this process?

   c. Scaling violations of structure functions in QCD lead to the Altarelli-Parisi [AP] equation. Write the mathematical expression of this equation and hence explain its physical interpretation. {Derivation of the AP equation is not required]

5. Explain the V-A theory of weak interaction and show that the weak interaction amplitudes $\mathfrak{M}$ are of the form: **10**

$$\mathfrak{M} = \frac{4G}{\sqrt{2}} J^{\mu} J_{\mu}^{\dagger} \ ,$$

where J^{μ} and J_{μ} are charge raising and charge lowering current and G is the weak coupling constant.

6. **a.** Write an expression for non-leptonic weak decay of K^+ meson and illustrate this process with a Feynman diagram. **2+4+4 =10**

b. Draw a Feynmann diagram for the following weak decay:
(i) $K^- = \mu^- + \bar{\nu}_\mu$. (ii) Inverse muon decay.

c. Give two examples of semi leptonic weak decay processes, accompanied by their respective Feynman diagrams.

7. **a.** Explain briefly the CP violation observed in neutral kaon systems. **5+5=10**

b. Give a description of the key concepts underlying the electroweak interaction.

8. **a.** Write down the names of the supersymmetry (SUSY) partners of leptons and quarks along with their symbols. Also mention their corresponding spins. **7+3=10**

b. i. State Goldstone's theorem.
ii. Under what condition does the Higgs boson become the Goldstone boson?

= = *** = =