2022/07

M.Sc. PHYSICS
FOURTH SEMESTER
ADVANCED HIGH ENERGY PHYSICS
MSP - 403C

(Use Separate Answer Scripts for Objective & Descriptive)

Duration : 3 hrs. Full Marks : 70

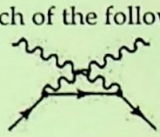
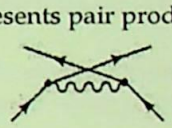
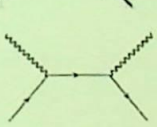
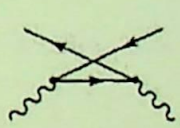
[PART-A: Objective]

Time : 20 min. Marks : 20

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

1. An electron and a positron annihilate to form a photon, which in turn produces a new electron-positron pair. This represents the interaction of two opposite charges. In QED this process is called
   a. Compton scattering
   b. Bhabha scattering.
   c. Pair production
   d. Pair annihilation.

2. Which of the following represent a spin half incoming anti-fermion?
   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. The dimension of Bjorken variable x is
   a. GeV
   b. GeV^{-1}
   c. GeV^{-2}
   d. dimensionless

6. If the positron wave function is defined as $\psi(x) = ae^{i/\hbar}(p.x)v^{(s)}(p)$, then according to Feynman rules for QED, the spinor $v^{(s)}$ satisfies the following momentum space Dirac equation
   a. $(\gamma^\mu p_\mu + mc)v = 0$
   b. $(\gamma^\mu p_\mu - mc)v = 0$

c. $(\gamma^{\mu}p_{\mu} - mc^2)v = 0$ d. $(\gamma^{\mu}p_{\mu} - m^2c^4)v = 0$

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

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

9. The reason for the existence of 3-gluon or 4-gluon vertex in Quantum Chromodynamics is
   a. quark-gluon interaction b. quark-quark interaction
   c. gluon-gluon-interaction d. virtual photon-gluon interaction

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

11. 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

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 $\overline{K^0} \rightarrow ? + \mu^- + \overline{\nu_{\mu}}$, what is the missing particle?
   a. e^+ b. π^+
   c. K^+ d. Σ^+

14. The dimension of weak coupling constant G is
   a. GeV b. GeV^{-1}
   c. GeV^{-2} d. dimensionless

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. According to supersymmetry (SUSY) all fermions should have bosonic partners with different values of
   a. mass b. charge
   c. spin d. parity

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 and they are of the order of
    a. $10^{-35}\ m$
    b. 10^{-35} Å
    c. 10^{-25} Å
    d. 10–25 m

19. The life time of a proton as predicted by Grand Unified Theory (GUT) is
    a. 10^{15} years
    b. 10^{34} years
    c. 10^{-3} secs
    d. 10^{34} secs

20. In supersymmetry the spin of 'gluino' (the superpartner of gluon) is
    a. 0
    b. 1
    c. 1/2
    d. 3/2

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PART-B : Descriptive

Time : 2 hrs. 40 min. Marks : 50

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

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

2. a. List the Feynman rules of Quantum electrodynamics. 4+6=10

   b. Draw the lowest-order Feynman diagram for the following processes:
   (a) Bhaba scattering
   (b) Moller scattering

3. a. Using Feynman rules of QED evaluate the scattering amplitude of Mott scattering process. 8+2=10

   b. Consider a process where a real photon interacts with an electron and the photon gets scattered off the electron. Hence, draw the lowest order Feynman diagram for this process.

4. Show that scaling violations of structure functions in quantum chromodynamics (QCD) lead to the Altarelli-Parisi equation. Explain the physical interpretation of this equation. 8+2=10

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. Also draw the Feynman diagram of this process. 4+4+2 =10

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

   c. What are the Cabibbo favoured charge raising transitions of quarks. Explain with Feynman diagrams.

7. a. Discuss briefly the CP violation of neutral kaon system. 5+3+1+ 1=10

   b. Explain briefly the phenomenon of neutrino oscillation.

   c. What does neutrino oscillation experiment suggest about neutrino mass?

   d. Name one experiment which provides the evidence of oscillation of atmospheric neutrinos.

8. a. What are the different types of weak interaction? Give one example of each. 4+6=10

   b. Write down the names of the supersymmetry (SUSY) partners of leptons and quarks along with their symbols. Also mention their corresponding spins.