(c) Which of the following reactions can occur ? State the conservation laws violated or/and in each case : 5

(i) $n \rightarrow p + e^- + \upsilon$

(ii) $p + p \rightarrow p + \Delta^0 + \Sigma^+$

(iii) $\pi^0 \rightarrow \gamma + \gamma$

(iv) $e^- + e^- \rightarrow \mu^+ + \pi^-$

(v) $e^+ + e^- \rightarrow \gamma$

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Total Pages : 06

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May 2026

M. Sc. (Physics) (Second Semester)

NUCLEAR AND PARTICLE PHYSICS

(PHP-104-V)

Time : 3 Hours] [*Maximum Marks : 75*

Note : It is compulsory to answer all the questions (1.5 marks each) of Part A in short. Answer any *four* questions from Part B in detail. Different sub-parts of a question are to be attempted adjacent to each other.

Part A

1. (a) If the half-life ($T_{1/2}$) of a radioactive sample is 10 hours, what is its average life time (τ) ? 1.5

(b) Why was the Neutrino hypothesized by Wolfgang Pauli during the study of beta decay ? 1.5

(c) Define radioactivity. State Soddy-Fajan's displacement law. 1.5

(d) Explain the physical origin of the Asymmetry Energy term in the Semi-Empirical Mass Formula. 1.5

(e) What is the primary functional difference between an Ionization Chamber and a Proportional Counter ? 1.5

(f) Define Isospin and give its importance. 1.5

(g) In low-energy *n-p* scattering, why is the scattering cross-section significantly higher for the triplet state (s = 1) than for the singlet state (s = 0) ? 1.5

(h) Under what specific condition does "Pair Production" occur, and what is the minimum threshold energy required for it ? 1.5

(i) Distinguish between Baryons and Mesons in terms of their quark composition and their statistical nature. 1.5

(j) A particle decay occurs as $\Lambda^0 \rightarrow p + \pi^-$. This decay is slow ($10^{-10}$ s). Based on conservation laws, which interaction is responsible for this decay and why ? 1.5

Part B

2. (a) What are the assumptions of Fermi theory ? Discuss in detail about the Fermi theory of beta decay and what is the correction made to match experimental β^- Spectra with theoretical one ? 10

(b) Describe and compare the kinematics of β^-, β^+ and electron capture process. 5

3. (a) What do you understand by radioactive equilibrium ? Also discuss about secular and transient equilibrium and also prove that N/τ = constant. 7

(b) In the following γ-transitions, find the most probable multipole order- $(5/2)^+ \rightarrow (3/2)^-$. 3

(c) Calculate the binding energy (in MeV) of Calcium - 40 nucleus ($^{40}_{20}Ca$) using the Semi-Empirical Mass Formula. Use the following simplified coefficients (in MeV) : 5

(i) Volume term (a_v): 15.5

(ii) Surface term (a_s): 16.8

(iii) Coulomb term (a_c): 0.72

(iv) Asymmetry term (a_{asym}): 23.0

(v) Pairing term : (δ)+12.0 for even-even, –12.0 for odd-odd, 0 for odd-A nuclei.

4. (a) Discuss the ground state properties of the deuteron. Use a square well potential to derive the expression for the binding energy and explain why the deuteron has no excited states. 10

(b) Using the Single-Particle Shell Model, determine the ground state spin (J) and parity (π) for the following two nuclei : 5

(i) $^{17}_{8}O$ (Oxygen-17)

(ii) $^{27}_{13}Al$ (Aluminum-27)

5. (a) What are Magic Numbers ? Explain how the inclusion of a strong Spin-Orbit (L.S) coupling term in the Shell Model potential successfully predicts these numbers. 10

(b) State and explain the Bethe-Bloch formula for the energy loss of heavy charged particles. 5

6. (a) Explain the mechanism of the Photoelectric effect and the Compton effect. Derive the expression for the Compton shift ($\Delta\lambda$). 7

(b) Explain the working of a Proportional Counter. What is 'Gas Multiplication' ? Briefly describe its construction and working. 8

7. (a) Classify the elementary particles in different categories. Discuss the Gellmann-Nishijima scheme for elementary particles. 5

(b) Schematically show the Baryon decuplet based on eight fold way. 5