10272

Name of the Department	**:**	**Physics and Astrophysics**
Name of the Course	**:**	**B.Sc. (H) – UGCF-NEP**
Name of the Paper	**:**	**DSE – Nuclear and Particle Detectors**
Semester	**:**	**VII**
Unique Paper Code	**:**	**2223010036**
Question Paper Set	**:**	**C**
Maximum Marks	**:**	**90**
Duration of the Paper	**:**	**Three hours**

Instructions for the candidate:

1. Write your roll number on the top immediately on receipt of this question paper.
2. Attempt **FIVE** questions in all.
3. **Question 1 is compulsory.**
4. Each question carries 18 marks.
5. Use of scientific calculator is allowed.

1. **Attempt any SIX parts from the following:** **(6×3 = 18)**

   a. Explain the mechanism of scintillation light production in organic scintillators.

   b. Compare the working principles of BF_3 proportional counters and ^3He counters for detecting thermal neutrons.

   c. A proportional counter produces on average 300 primary ion pairs for an incident particle. The gas multiplication (gain) is $G = 5 \times 10^3$. Each electron charge $q = 1.602 \times 10^{-19}\ C$. Find the total collected charge per pulse (in coulombs).

   d. With the help of diagram, demonstrate *paralyzable dead time* model in detection.

   e. How is avalanche formed in a gas chamber?

   f. Outline the working principle of a charge sensitive pre-amplifier.

   g. Determine the thermal noise voltage in a 200 Ω resistor at 27°C for a system having a bandwidth of 0 to 500 MHz.

2. a. Discuss the process by which heavy charged particles interact with matter and derive and expression for their stopping power. (6)

   b. Explain and characterize the Cherenkov Radiation. What is the necessary condition for the emission of Cherenkov radiation? (6)

   c. Calculate the stopping power for 4 MeV proton moving in Au medium. (6)

3. a. Discuss the different modes of detector operation. Explain how the pulse shape depends upon the time constant of the measuring circuit. (6)

   b. Define the intrinsic efficiency of a detector and on what parameters does it depend? How does it differ from the extrinsic efficiency of a detector? (6)

   c. Calculate the amplitude of the voltage pulse produced by collecting a charge equal to that carried by 10^6 *electrons* on a capacitance of 100 pF.

(Given $e = 1.602 \times 10^{-19}$) (6)

4. a. Explain why the Geiger–Müller counter produces pulses of nearly the same amplitude for all types of ionizing radiation. Discuss the role of quenching gas in ensuring stable operation of the detector. (6)

   b. How does an inorganic scintillator counter detect nuclear radiation? Explain the role of the crystal lattice structure and activator impurities in the scintillation process. (6)

   c. A gamma-ray photon of energy 1 MeV is incident on a free electron at rest and is scattered through an angle of 90°. Derive the expression for the energy of the scattered photon using the Compton scattering formula. Calculate the scattered photon's energy and the corresponding kinetic energy imparted to the recoil electron. (3+3)

5. a. What is the basic working principle of a silicon drift detector? Explain how the drift of charge carriers inside the silicon helps in producing an accurate electrical signal. (2+4)

   b. Explain how a boron-loaded scintillator detects slow neutrons. Describe conceptually how the presence of boron enhances neutron sensitivity through the $\mathrm{B}(n, \alpha)\mathrm{Li}$ reaction. (6)

   c. Assume that the Fano factor in germanium were half the currently assumed value. What quantitative effect would this change have on the theoretically obtainable energy resolution? Assume that $W = 26.2\ eV/ion$ pair and the Fano factor $F = 0.17$ for argon, find the mean and expected standard deviation in the number of ion pairs formed by the absorption of $1\ MeV$ of radiation energy. (6)

6. a. Why, despite the crucial need for timing performance in nuclear physics, designers often retain TTL logic for general control over slower functions, even when ECL is available as the fastest form of digital logic? (6)

   b. What is the function of a TAC (time to amplitude convertor)? Explain its operation with the help of pulse diagrams. (2+4)

   c. What is electronic coincidence? Explain the summing method for determining the coincidence of two signals. (2+4)

7. a. Describe the working principle of a gamma camera used in nuclear medicine. Explain the functions of the collimator, scintillation crystal, and photomultiplier tubes. (3+3)

   b. Describe any two applications of nuclear detectors for particle physics and astrophysics experiments. (6)

   c. A gamma photon with an energy of $140\ keV$ (from ${}^{99m}_{43}Tc$ isotope) interacts in a scintillation crystal producing 4.0×10^3 light photons. If the quantum efficiency of the photomultiplier tube (PMT) is 25%, how many photoelectrons are produced at the photocathode? (6)