

2026

PHYSICS

(Major)

Paper : PHY0600104

(Nuclear and Particle Physics)

Full Marks : 60

Time : 2½ hours

*The figures in the margin indicate full marks
for the questions.*

1. Answer the following questions : 1×8=8

- (a) What is the relation between mass number and nuclear radius?
- (b) Why are even-even nuclei most stable?
- (c) What is the relation between mean-life time and half-life time of a radioactive substance?
- (d) Why is energy of α -particles discrete in α -decay?

(2)

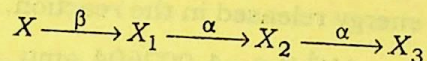
- (e) What is the difference between X-rays and γ -rays?
- (f) At what scattering angle is the wavelength shift in Compton effect equal to the Compton wavelength?
- (g) Write the principle of gas-filled detector.
- (h) What is the difference between π -mesons and K-mesons?

2. Answer any six of the following questions :
2×6=12

- (a) What is the mass number A of a nucleus whose radius R is 2.5 fm?
- (b) Justify that the nuclei are made of protons and neutrons rather than protons and electrons.
- (c) If the half-life of a radioactive substance is 30 days, then calculate its decay constant.

(3)

- (d) A radioactive nucleus disintegrates according to the following sequence :



If the mass number and atomic number of X_3 are 172 and 69 respectively, what is the mass number and atomic number of X ?

- (e) Write any two features of Cherenkov radiation.
- (f) A proton is stopped in an ionization chamber producing 10^5 ion-pairs. Energy required to produce an ion-pair is 35 eV.
- (i) What is the kinetic energy of proton entering the ionization chamber?
- (ii) What is the amount of charge collected on each plate?
- (g) Explain why, in nuclear fission, the neutrons are more effective as the bombarding particle.

- (h) In a star, three α -particles fuse together to form a ${}^{12}_6\text{C}$ nucleus. Calculate the energy released in the reaction. Given—

$$M({}_2^4\text{He}) = 4.002604 \text{ amu}$$

$$M({}_6^{12}\text{C}) = 12 \text{ amu}$$

- (i) Explain the concept of charge conjugation.
- (j) Give the quark structure of a proton and neutron.

3. Answer any *four* of the following questions :

$$5 \times 4 = 20$$

- (a) Explain the terms 'packing fraction', 'mass defect' and 'binding energy' of a nucleus. How is binding energy related with the stability of the nucleus? $3+2=5$
- (b) Calculate the average binding energy per nucleon for a U^{238} nucleus in MeV. The mass of U^{238} atom is 238.05078 amu and it is composed of 92 protons and 146 neutrons. The masses of proton, neutron and electron are 1.00728 amu, 1.00867 amu and 0.00055 amu respectively. 5

- (c) Explain qualitatively the phenomenon of γ -decay in nuclei. 5
- (d) Write a short note on any *one* of the following : 5
- (i) Ionization chamber
- (ii) Proportional counter
- (e) Derive an expression for the change in wavelength of scattered photon in Compton scattering. 5
- (f) Distinguish between nuclear fission and fusion. Explain the principle of a nuclear reactor. $2+3=5$
- (g) Discuss the classification of elementary particles. 5
- (h) Obtain the classical formula for energy loss of heavy charged particles through matter and then introduce relativistic correction to obtain Bethe-Bloch formula. 5

4. Answer any *two* of the following questions :

$$10 \times 2 = 20$$

- (a) State the laws of radioactive disintegration and derive the Rutherford-Soddy law. Explain the term 'mean-life' of a radioactive substance. Show that the mean-life of an atom of a radioactive substance is the reciprocal of its decay constant.

$$5 + 5 = 10$$

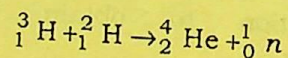
- (b) Plot the distribution of kinetic energy of β -particles and state why the energy distribution of β -decay is continuous. How did it lead to discovery of neutrino? Explain Pauli's neutrino hypothesis for β -decay from a radioactive nucleus.

$$1 + 2 + 2 + 5 = 10$$

- (c) Describe the construction and working of a Geiger-Muller (GM) counter. What are its limitations?

$$8 + 2 = 10$$

- (d) What is Q -value of nuclear reaction? How can it be determined? Calculate the Q -value of the following reaction :



Given—

$$M({}^3_1\text{H}) = 3.0169982, \quad M({}^2_1\text{H}) = 2.0147361,$$

$$M({}^4_2\text{He}) = 4.0038727, \quad M({}^1_0\text{n}) = 1.0089832$$

all in amu. Also mention the above reaction is exoergic or endoergic.

$$2 + 3 + 4 + 1 = 10$$

- (e) What are baryons and leptons? Explain the conservation law for lepton and baryon number with example.

$$4 + 6 = 10$$
