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?

(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.

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

$$X \xrightarrow{\beta} X_1 \xrightarrow{\alpha} X_2 \xrightarrow{\alpha} X_3$$

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 $^{12}_{6}C$ nucleus. Calculate the energy released in the reaction. Given—

$M(^{4}_{2}He) = 4{\cdot}002604$ amu

$M(^{12}_{6}C) = 12$ 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 : 5×4=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 : 10×2=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 :

$$^{3}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$$

(Continued)

Given—

$M(^{3}_{1}H) = 3{\cdot}0169982$, $M(^{2}_{1}H) = 2{\cdot}0147361$,

$M(^{4}_{2}He) = 4{\cdot}0038727$, $M(^{1}_{0}n) = 1{\cdot}0089832$

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

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