

Total number of printed pages-11

3 (Sem-5/CBCS) PHY HE 5

2025

**PHYSICS**

(Honours Elective)

Paper : PHY-HE-5056

*(Nuclear and Particle Physics)*

Full Marks : 80

Time : Three hours

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

1. Give short answers to the following questions : **(any ten)** 1×10=10
- (a) What are the particles responsible for mediating strong and electromagnetic interaction ?
- (b) What is the strongest force in nature ?
- (c) What is the significance of magic number ?

(d) According to the meson field theory a neutron emits a  $\pi^-$  meson and is converted into a proton. Is the statement true?

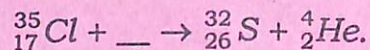
(e) What does the asymmetry term in semi empirical mass formula represent?

(f) What is the minimum energy of gamma ray photon to undergo pair production?

(g) Why pair production cannot take place in free space?

(h) What is the type of nuclear reaction represented by  ${}^{16}_8\text{O} \left( {}^2_1\text{H}, {}^3_1\text{H} \right) {}^{15}_8\text{O}$ ?

(i) Complete the nuclear reaction

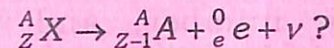


(j) If the  $Q$ -value of a nuclear reaction is zero, what does it represent?

(k) What happens to atomic number, mass number and actual mass when a nucleus emits gamma ray photon?

(l) What would be the energy spectra of neutrino in electron capture process?

(m) What is radioactive decay represented by the following nuclear reaction



(n) Will there be any difference between energy spectra of electrons and positrons in  $\beta$ -decay process?

(o) What is the meaning of non-zero value of quadrupole moment of a nucleus?

(p) Is the nuclear force spin dependent?

(q) Which one is having maximum binding energy  ${}^{56}\text{Fe}$  or  ${}^{208}\text{Pb}$ ?

(r) If the nuclear radius of  ${}^{27}\text{Al}$  is 3.6 Fermi, find the approximate nuclear radius of  ${}^{64}\text{Cu}$  in Fermi?

2. Briefly answer the following questions :

**(any five)**

2×5=10

(a) The quark composition of  $\pi^-$  is  $\bar{u}d$  and that of proton is  $uud$ . Show that these compositions give the required charge, baryon number, strangeness and spin of the respective particles.

- (b) What are strange particles? How are the strangeness quantum number, baryon number, and the third component of isotopic spin related to the charge of the elementary particle?
- (c) What is Cherenkov radiation?
- (d) What is quenching of a GM counter?
- (e) A beam of monoenergetic gamma rays is incident on an aluminium sheet of thickness 10cm. The sheet reduces the intensity of the beam to 21 percent of the original. Calculate the linear and mass absorption co-efficient, given density of Al =  $2700 \text{ kg/m}^3$ .
- (f) How are the energy spectra of alpha particle different from that of beta particle and why?
- (g) What is mass defect and packing fraction?
- (h) Why neutron number exceeds proton number in the medium and heavy nuclei?

- (i) What is the saturation property of nuclear force?
- (j) Calculate the binding energy of a deuteron nucleus? Given, mass of deuteron =  $2.013553 \text{ a.m.u}$ , mass of proton =  $1.007276 \text{ a.m.u}$ , and mass of neutron =  $1.008665 \text{ a.m.u}$ .

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

5×4=20

- (a) (i) What are leptons?
- (ii) How many leptons are there? Write their names.
- (b) (i) What is the most serious limitation of the action of cyclotron?
- (ii) What is the advantage of linear accelerator over cyclotron?
- (c) What are the *three* key features used in the detection of nuclear radiation?
- (d) How neutrino hypothesis explains continuous nature of  $\beta$ -spectrum?
- (e) (i) Give a brief outline of the determination of the energy of  $\alpha$ -particle experimentally.

(ii) An  $\alpha$ -particle from radioactive nuclei travel along a semicircle of radius  $20\text{ cm}$  in a magnetic field of flux density  $1.763\text{ web/m}^2$ . Find the velocity and energy of the particles. Given,  $e/m$  for  $\alpha$ -particle =  $4.824 \times 10^7\text{ Ckg}^{-1}$ , Mass of  $\alpha$ -particle =  $6.643 \times 10^{-27}\text{ kg}$ .

(f) (i) What is meson theory of nuclear force?

(ii) How it can be established that mass of  $\pi$  meson is almost 275 times that of electron?

(g) What are the characteristics of nuclear force?

(h) How the release of large amount of energy during fission and fusion can be explained from binding energy per nucleon against mass number curve?

4. Answer the following questions : **(any four)**  
 $10 \times 4 = 40$

(a) (i) What are fundamental interactions in nature?

(ii) What do you mean by quarks? How many possible quarks are there? Give the charge and quantum number associated with each quark.  $5+5=10$

(b) (i) What are hadrons?

(ii) A  $\mu^-$  meson decays into an electron ( $e^-$ ) and a pair of neutrinos ( $\nu_\mu, \bar{\nu}_e$ ). Calculate the maximum available energy for the process and the average electron energy. Assume  $m_e = 207m_\mu$ .

(iii) Check if the reaction

$\pi^- + p \rightarrow \Lambda^0 + K^0$  is allowed or forbidden?  $5+2\frac{1}{2}+2\frac{1}{2}=10$

(c) (i) What is the basic resonance condition of a fixed frequency cyclotron?

(ii) Why a cyclotron is not suitable for energizing an electron?

- (iii) What is the energy to which protons can be accelerated in a cyclotron with a dee-dia of  $2m$  and a magnetic field of flux density  $0.72 \text{ Wb/m}^2$ ? Mass of proton =  $1.673 \times 10^{-27} \text{ kg}$ .  $5+2\frac{1}{2}+2\frac{1}{2}=10$
- (d) (i) What is dead time, resolving time, and recovery time of GM counter?
- (ii) A GM counter has dead time  $400 \mu\text{s}$ . What are the true counting rates when the observed rates are (i) 100 per minute, and (ii) 1000 per minute?  $7+3=10$
- (e) (i) Define Q-value of a nuclear reaction.
- (ii) What is exoergic and endoergic reaction?
- (iii) Find the Q-value and threshold energy for the reaction
- $${}^{19}\text{F}(n, p) {}^{19}\text{O}.$$
- Given, atomic masses are
- $${}^{19}\text{F} = 18.99840 \text{ amu},$$
- $${}^1_1\text{H} = 1.007825 \text{ amu},$$
- $${}^{19}\text{O} = 19.003577 \text{ amu}, \text{ and}$$
- $${}^1_0\text{n} = 1.008665 \text{ amu}.$$

$$4+2+4=10$$

- (f) (i) What are different types of nuclear reactions?
- (ii) What are the conservation laws applicable to a nuclear reaction?  $5+5=10$
- (g) (i) What is alpha disintegration energy?
- (ii) Calculate the kinetic energy of alpha particle in the following decay
- $$\text{Pu}^{239} \rightarrow \text{U}^{235} + \text{He}^4$$
- Given,
- $$M(\text{Pu}^{239}) = 239.052158 \text{ MeV},$$
- $$M(\text{U}^{235}) = 235.043925 \text{ MeV},$$
- $$M(\text{He}^4) = 4.002603 \text{ MeV}.$$
- (iii) Give the quantum mechanical explanation of alpha decay.  $3+3+4=10$
- (h) (i) What is the range of alpha particles?

- (ii) What is Geiger-Nuttall law ?
- (iii) Justify that the radioactive element of large decay constant emits high energy alpha particles.
- (iv) Given that the range, in standard air, of the alpha particles from radium ( $T_{1/2} = 1622$  years) is  $3.36$  cm., whereas, from polonium ( $T_{1/2} = 138$  days) his range is  $3.85$  cm. Calculate the half-life of RaC for which the alpha particle range is  $6.97$  cm.

$$2+2+2+4=10$$

- (i) (i) What are the significant similarities between a drop of liquid and an atomic nucleus ?
- (ii) What are the evidences of shell model of nucleus ?  $5+5=10$
- (j) (i) Write the semi empirical mass formula and explain its various terms.

- (ii) Using semi empirical mass formula, show that the atomic number ( $Z$ ) of the most stable nucleus ( $A$ ) is given by

$$Z = \frac{A}{2 + 0.0157 A^{2/3}},$$

the best values of constants in semi-empirical mass formula, expressed in MeV are

$$a_v = 15.760, a_s = 17.810, a_c = 0.711, \\ a_{asym} = 23.702, \delta = 0.$$

$$5+5=10$$