B.Sc. 6th Semester (Honours) Examination, 2025 (CBCS)

Subject : Physics

Course : DSE-3

(Nuclear and Particle Physics)

Time: 3 Hours **Full Marks: 60**

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

1. Answer *any ten* questions from the following: 2×10=20

(a) Assuming constancy of nuclear charge density show that the radius of a nucleus is proportional to $A^{1/3}$, where A is the mass number of the nucleus.

(b) Explain the 'saturation' and 'spin dependence' properties of nuclear force.

(c) What do you mean by the conservation of parity in a nuclear process?

(d) The binding energy of $^{20}_{10}Ne$ is 160.647 MeV. Find its atomic mass.

(e) Calculate the barrier height between the daughter nucleus and the α-particle in a α-decay of $^{238}_{92}U$.

(f) Explain the continuous spectra of β-decay.

(g) Complete the following reactions:

$^{10}_{5}B + ^{1}_{0}n \rightarrow ^{7}_{3}Li + ?$

$^{9}_{4}Be + ^{1}_{1}H \rightarrow ^{8}_{4}Be + ?$

(h) X-ray of wavelength 1Å is scattered by a carbon block. The scattered radiation is observed at 180°. Find the kinetic energy of the recoil electron (Compton wavelength = 0.024 Å).

(i) Can a cyclotron be used to accelerate electrons? Justify.

(j) What kind of electric field is applied in an ionisation chamber and a proportional counter?

(k) What is internal conversion? How does it differ from γ-emission?

(l) Write a short note on 'compound nuclear reaction'.

(m) Write down the quark content of Σ^+ and K^0.

(n) Mention the positions of Σ^+ and Σ^- in $I_3 - Y$ plot (I_3 = z-component of isospin, Y = Hypercharge).

(o) What are the exchange particles in strong e-m and gravitational interactions?

2. Answer *any four* questions from the following: 5×4=20

(a) Define the binding energy of a nucleus. Draw the curve of the binding energy per nucleon with the mass number. Using the curve explain the release of energy in fission and fusion. 1+1+3

(b) Write down the similarities between a liquid drop and a nucleus. Using Weizacker's semi-emperical formula obtain an expression of the atomic number (z) of the most stable nucleus for a mass number $A(a_c = 0.7053, a_a = 23.702\ \text{MeV})$. 2+3

(c) Obtain an expression of the Q-value and the condition of different types of β-decay in terms of atomic mass.

(d) Explain the principle of a linear accelerator with diagram. Obtain expression of lengths of cylinders inside the accelerator. 4+1

(e) Write down the Einstein's photo-electric equation. Explain the threshold frequency and stopping potential using the equation.

A metal has a work function of 2.5 eV. Will the light of wavelength 400 nm cause photoemission? 1+2+2

(f) Write down the basic working principle of a scintillation detector. Briefly discuss with diagram about the working principle of a photo-multiplier tube used in scintillation detector. 2+3

3. Answer *any two* questions from the following: 10×2=20

(a) (i) What is the Q-value in a disintegration process? Show that the Q-value in α-disintegration can be expressed in terms of the kinetic energy of the α-particle and the mass number of disintegrating nucleus.

(ii) Obtain an expression of Geiger-Nuttal law using Gammow theory of α-decay. (1+3)+6

(b) Briefly discuss about the shell model of a nucleus. Using the model explain the stability of magic nuclei. Find the ground state, spin and parity of $^{17}_{8}O$ and $^{39}_{19}K$. 6+2+2

(c) (i) Obtain an expression of Q-value of the following reaction $a + X = Y + b$ in terms of the kinetic energies of the product particles and projectile.

(ii) Obtain an expression of threshold energy of endoergic reaction. Calculate the threshold energy required to initiate the reaction $^{31}P(n,p)^{31}Si$. 4+(3+3)

(d) (i) Write down the relative strength of different types of interactions. (Strong, Gravitational and Electromagnetic)

(ii) Mention the category of the following particles: μ^+, Ξ^-, η^0 and π^-.

(iii) Write down conservation laws of z-component of isospin and hypercharge of the following reactions:

(I) $\pi^- + p \rightarrow n + \pi^0$, (II) $p + p \rightarrow p + \Lambda^0 + \Sigma^+$.

(iv) Write down the charge and Baryon number of $\bar{d}$ and s quarks. 2+2+4+2

[Useful Data:

Planck's Constant (h) = 6.626×10^{-34} J-s

1 u = 1.66×10^{-27} kg = 931.5 MeV

$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N-m^2-C^2

$R_0 = 1.2$ fm

Charge of electron = 1.6×10^{-19} C

Mass of proton = 1.00814 u

Mass neutron = 1.00898 u

Mass of $^{31}P = 30.98356$ u

Mass of $^{31}Si = 30.98515$ u]
