B.Sc. 6th Semester (Honours) Examination, 2023 (CBCS)

Subject : Physics

Course : DSE-3:(6)

(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 applicable.

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

(a) Find the density of nucleons in ${}^{12}_{6}C$ nucleus.

(b) What will be the quadrupole moment of a system containing two dipoles of dipole moment $\vec{p}$ placed in opposite direction and separated by a distance d? What can you say about quadrupole moment of a spherical nucleus?

(c) Explain the term 'saturation and charge independence of nuclear force'.

(d) What is long range α-particle and fine structure of α-ray spectrum?

(e) What is internal conversion ? How does it differ from β^- decay?

(f) What do you mean by non-conservation of parity in β decay?

(g) Define nuclear reaction cross-section. What is its unit?

(h) Complete the following reactions:

$${}^{24}_{12}Mg + {}^{1}_{0}n \rightarrow {}^{24}_{11}Na +$$

$${}^{12}_{6}C + {}^{2}_{1}H \rightarrow + {}^{1}_{1}H$$

(i) Which of the following materials (work function of each material is given within bracket) can be used for designing photocell operable in visible light?

Tungsten ($\phi = 4.5\ eV$) and Lithium ($\phi = 2.3$ eV).

(j) What is Compton wavelength? Find the Compton shift at the scattering angle 180°.

(k) Briefly explain the role of dynodes in scintillation detector.

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

(m) A proton accelerating cyclotron having the applied voltage frequency as 2.2×10^7 cycles/sec. Calculate the magnetic field strength for resonance.

(n) What is pair production? Obtain the minimum energy of photon required for pair production.

(o) Write down the charge and strangeness of up and strange quark.

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

(a) (i) Express the Q-value in orbital electron capture and β^+ decay in terms of atomic masses.

(ii) Determine the energy of the neutrino that is produced when $^{7}_{4}Be$ undergoes electron capture at rest. 3+2

(b) (i) For odd–A nuclei the nuclear mass can be expressed as $M(z, A) = \alpha A + \beta Z + \gamma Z^2$, where α, β and γ are constants. Here, Z and A correspond to the atomic number and mass number of the nucleus. Show that odd–A nuclides on either side of the mass parabola decay to a stable state having greatest binding energy.

(ii) Why are two parabolas obtained for even-A nuclides? 3+2

(c) (i) What are magic numbers? Using the shell model explain the presence of magic nuclei.

(ii) Calculate the spin-parity of $^{41}_{19}K$ and $^{45}_{20}Ca$ nuclei using shell model. (1+2)+2

(d) (i) Draw graphs of observed photoelectric current with retarding potential for two different frequencies of incident light. Explain the graph using Einstein's quantum theory of light.

(ii) Light of wavelength 2000Å falls on aluminium surface which has work function of 4.2 eV. Calculate the maximum kinetic energy of photoelectrons. (1+2)+2

(e) Discuss the construction and working of a semiconductor detector. Mention one advantage and one disadvantage of such detector. 3+2

(f) Obtain the expression of threshold energy for endoergic reaction. Calculate the energy required to remove the least tightly bound neutron from $^{45}_{20}Ca$. 3+2

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

(a) (i) What is binding energy of a nucleus? Draw the curve of binding energy per nucleon with mass number. Why is there a peak at A=4?

(ii) Using the curve, explain the release of energy in fusion of light nuclei and fission of heavy nuclei.

(iii) Calculate the binding energy (in MeV) of deuteron. (1+2+1)+(2+2)+2

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

(ii) Obtain the expression of Geiger-Nuttal law using Gammow's theory of α-decay.

(iii) Calculate the height of the potential barrier between daughter nucleus and the α-particle in α-decay of $^{238}_{92}U$. (1+2)+5+2

(c) (i) Mention the nature of interaction of the following processes:

(I) Beta decay of nucleus

(II) Binding of nucleons to form a nucleus

(III) Confinement of quarks in neutron.

(IV) Friction of a ball rolling on the ground

(ii) Why are the following reactions forbidden?

(I) $e^- + e^+ \rightarrow \pi^- + \mu^+$

(II) $\Sigma^+ \rightarrow K^- + p + p$

(III) $\pi^- + p \rightarrow \pi^+ + \Lambda^0$

(iii) Write down the quark content of Ξ^-, Σ^0 and K^0. 4+3+3

(d) (i) Obtain the Rutherford scattering formula.

(ii) Describe the working principle of a linear accelerator with a proper diagram. 6+4

[Useful Data:

$R_0 = 1{\cdot}2$ fm

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

1 u = $1{\cdot}661 \times 10^{-27}$ kg = 931·5 MeV

Mass of proton = 1·00727647 u

Mass of neutron = 1·008665 u

Mass of electron = 0·00054858 u

Mass of deuteron= 2·01355321 u

Charge of proton =$1{\cdot}6 \times 10^{-19}$ C

Mass of ^7_4Be = 7·01693 u

Mass of $^{7}_{3}Li = 7{\cdot}016$ u

Mass of $^{40}Ca = 39{\cdot}962589$ u

Mass of $^{39}Ca = 38{\cdot}970691$ u]
