B.Sc. 6th Semester (Honours) Examination, 2024 (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) Write down four properties of nuclear force.

(b) The amount of energy required to remove a neutron from the nucleus of $^{42}_{20}Ca$ is more than the energy required to remove a proton from the same nucleus – Explain.

(c) Why does the peak occur in the ionisation curve near the range of α-particles?

(d) $^{12}_{5}B$ is an unstable nucleus but $^{12}_{6}C$ is stable – Why?

(e) What do you mean by internal conversion?

(f) In photoelectric effect, the stopping potential is 2 volt for the incident light of wavelength 4000Å. Calculate the work function of the material.

(g) What is Cérenkov radiation?

(h) What is Q-value of a nuclear reaction? What is the significance of Q-value?

(i) Write one example each of (p, α) and (d, n) type reactions.

(j) A uniform magnetic field of 2 Wb/m^2 is used in a cyclotron to accelerate protons. How rapidly the electric field between the dees should be reversed?

(k) Mention two difficulties for the detection of neutron.

(l) The polonium isotope $^{210}_{84}Po$ is unstable and emits a 5.3 MeV alpha particle. Find the atomic mass of daughter nucleus.

(m) The charge and spin angular momentum of a proton are $+e$ and $\frac{\hbar}{2}$ respectively. How can these values are obtained from its quark constituents?

(n) What are the exchange particles in strong electromagnetic and gravitational interactions?

(o) Mention any two conservation laws that are being violated with proper explanation in the following decay: $p \rightarrow \pi^0 + e^+$.

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

(a) (i) Define binding energy of a nucleus. Calculate the binding energy of a deuteron nucleus.

(ii) A nucleus with mass number 235 splits into two fragments whose mass numbers are in the ratio 2:3. Find the separation between the fragments at the moment of splitting. (1+2)+2

(b) (i) Draw the single-particle energy levels up to s-d shell in the nuclear shell model with spin-orbit interaction. What are the ground state spin-parity of $^{13}_{6}C$ and $^{33}_{16}S$ nuclei according to shell model?

(ii) Why nuclei with magic numbers of neutrons or protons are more abundant than other nuclei with similar mass number? (1+2)+2

(c) Briefly describe the operation of G-M counter. How the 'quenching' is done in the G-M counter using a mixture of gases? 3+2

(d) Derive an expression for the wavelength shift in Compton scattering.

(e) (i) $^{34}_{17}Cl$ nucleus decays to $^{34}_{16}S$ by emitting β particles. The $^{34}_{16}S$ nucleus has two excited states with energies 2.1 MeV and 3.22 MeV above the ground state. The ground state energy of $^{34}_{17}Cl$ nucleus is 4.5 MeV. Show all possible transitions mentioning the energies of the β and γ rays.

(ii) Why is the pair creation not possible in vacuum? 3+2

(f) (i) Mention the category (lepton, meson, baryon) of the following particles:

ν_e, Ω^-, Ξ^- and K^0

(ii) What are the quark constituents of π^+ and $\sum^-$?

(iii) Why the quark in a hadron have different colors? 2+2+1

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

(a) (i) Obtain the expression of the binding energy considering the volume effect, surface effect and Coulomb effect using liquid drop model of nucleus.

(ii) Write down the Bethe-Weizsäcker mass formula mentioning each term. Show that for $N = Z$ nuclei the average binding energy per nucleon is maximum around $Z \approx 26$. [Neglect the pairing energy term. Here, $a_v = 15.835MeV$, $a_s = 18.33\,MeV$ and $a_c = 0.714MeV$]

(1+2+2)+(2+3)

(b) (i) Briefly discuss the working principle of a cyclotron with a schematic diagram.

(ii) How does the principle of cyclotron and betatron work in electron synchrotron? 6+4

(c) (i) What were the observational discrepancies of β^- decay of nucleus that led to neutrino hypothesis? How were the discrepancies resolved by neutrino hypothesis?

(ii) Derive the condition of β^- decay in terms of atomic mass.

(iii) The isotope $^{12}_{5}B$ undergoes β^- decay to $^{12}_{6}C$. $^{12}_{6}C$ has an excited state of nucleus ($^{12}_{6}C^*$) at 4.041 MeV above the ground state. Find the maximum energy of the emitted β^- particle in MeV. [Difference in atomic mass of $^{12}_{5}B$ and $^{12}_{6}C$ is 0.014 u]

(2+4)+2+2

(d) (i) Mention the quantities which are conserved in a nuclear reaction.

(ii) Define nuclear reaction cross-section. What is its unit? Show that the number of surviving particles decreases exponentially with increase in the thickness of a slab.

(iii) When a nucleus of $^{7}_{3}Li$ is bombarded with a proton, two α-particles are formed. Calculate the kinetic energy of each α-particle assuming the kinetic energy of proton negligible. 3+(1+1+3)+2

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

$1\,u = 1.661 \times 10^{-27}$ kg = 931.5 MeV

Mass of $^{210}_{84}Po = 209.9829$ u

Mass of $^{4}_{2}He = 4.0026$ u

$R_0 = 1.2$ fm

Charge of electron = $1.6 \times 10^{-19} C$

Mass of electron = 0.00054858 u

Mass of proton= 1.007825 u

Mass of neutron = 1.008665 u

Mass of deuteron = 2.01355321 u

Mass of $^{7}_{3}Li = 7.016004$ u

B.Sc. 6th Semester (Honours) Examination, 2024 (CBCS)

Subject : Physics

Course : DSE-3(7) (OR)

(Biophysics)

Time: 3 hours **Full Marks: 60**

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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) Write the functions of a mitochondria.

(b) Distinguish between cell-wall and cell-membrane.

(c) Define Allometric scaling.

(d) State the types of cellular reproduction.

(e) What are the four stages of cellular reproductions?

(f) What are the approximate sizes of typical proteins found in human body?

(g) Mention the range in size of a nucleic acid.

(h) What are the energy requirements of a bacterial cell?

(i) Define DNA replication process.

(j) What are the steps of protein replication?

(k) What do you mean by transcription of DNA?

(l) How many genes are there in a typical human cell?

(m) What is the number of genes present in a RBC cell?

(n) Define ecosystem.

(o) What is a biosphere?

(p) What is self-sustaining ecosystem?

(q) How many models of ecosystems are there? Name them.

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

(a) Discuss the energy exchange mechanisms in a living cell with its environment.

(b) Briefly discuss about human metabolites.

(c) Compare time-scale and spatial-scale of biological systems.

(d) Briefly discuss about the secondary structure of proteins?

(e) Discuss briefly about the molecular evolution.

(f) Discuss about a particular model of Cellular Dynamics.

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

(a) Discuss in detail the simple random walk and the lazy random walk.

(b) (i) What is genotype-phenotype map? Write its two applications.

(ii) Draw the structure of a human brain indicating the main three parts.

(c) Discuss the basic structure and functions of protein.

(d) What is a neuron? Mention their different types. Briefly mention the structure and function of a neuron.