

**B. Sc. Semester VI (Honours) Examination, 2020 (CBCS)**

**Subject: Physics**

**Paper: DSE-3 (Nuclear and Particle Physics)**

Time: 3 Hours

Full Marks: 60

*The figures in the margin indicate full marks. Candidates are requested to give their answers in their own words as far as practicable.*

1. Answer **any six** of the following questions : 5 × 6 = 30
- (a) (i) Assuming uniform nuclear matter density, calculate the proton density of a symmetric nucleus  ${}^A_ZX$ . (Given : Nuclear radius parameter = 1.2 fm.)
- (ii) Express atomic mass unit in MeV.
- (iii) Draw schematically the curve showing the variation of binding energy per nucleon versus the mass number and discuss the characteristic features of this curve. 5
- (b) (i) What are the important properties of nuclear force which are responsible to exhibit saturation phenomenon of it?
- (ii) Express the mass of a nucleus in terms of its binding energy.
- How can the fragmentation of a heavy nucleus into two and amalgamation of two light nuclei into a single one be explained in the light of binding energies of nuclei?
- (iii) It is found that even A isobars generally have more than one stable isotopes in nature - Explain. 5
- (c) (i) Show that nucleon separation energy can be expressed as  $S_n = A \frac{d\epsilon}{dA} + \epsilon$ , where,  $\epsilon$  denotes the binding energy per nucleon. Hence, calculate  $S_n$  for a nucleus having  $A = 240$  and  $\frac{d\epsilon}{dA} \approx 1/160$  and  $\epsilon = 6.3$  MeV.
- Comment on the shape of the nuclei having 1) positive and 2) negative quadrupole moments.
- (ii) In spite of the nucleus being a highly dense object, it is assumed in shell model theory that the nucleons move independently in the potential well - Justify.
- (iii) Write down the shell model configuration of odd nucleon for the  ${}^{13}_6C$  nucleus. 5

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- (d) (i) The  $\alpha$ -decay from a nucleus is more favourable than the emission of a single nucleon – Why is this so?
- (ii) Why neutrinos have been proposed to explain the  $\beta$ -decay spectra instead of photons?
- (iii) Determine the electric and magnetic multi polarities of the following  $\gamma$  transitions:
- 1)  $2^+ \rightarrow 0^+$  ; 2)  $1^+ \rightarrow 0^+$  5
- (e) (i) In the decay :  ${}^{226}_{88}\text{Ra} \rightarrow {}^{222}_{86}\text{Rn} + {}^4_2\text{He}$ , the coulomb barrier encountered by an  $\alpha$  particle during its emission is 34 MeV, whereas, the  $\alpha$  disintegration energy is found to be 4.9 MeV. What would be the possible result from classical point of view? How can the decay process can be explained on the basis of an alternative theory?
- (ii) What is the range-velocity relationship for  $\alpha$  particles while travelling in a material medium? Write down the Geiger-Nuttall law explaining different terms involved in it.
- (iii) Draw schematically the  $\beta^{\mp}$  spectra. Explain the end point energy. 5
- (f) (i) Define the Q-value of a nuclear reaction. What is a Q-equation?
- (ii) What is the basic assumption in compound nucleus theory of nuclear reaction?
- (iii) Show that the photoelectric effect can not take place with a free electron. 5
- (g) (i) Discuss the basic principle of a scintillation detector.
- (ii) Show that in a cyclotron, the radial separation between the successive trajectories decrease with the increasing number of revolutions of the charged particles. Compare the cyclotron resonance frequencies of a proton, a deuteron and an  $\alpha$ -particle. 5
- (h) (i) In the framework of quark model, how the strong nuclear interaction differs from the electromagnetic interaction?
- (ii) Why is  $\Lambda^0$  is called a strange particle?
- (iii) Name the fundamental leptons.
- (iv) Write the examples of two pseudo-scalar mesons. 5

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2. Answer **any three** of the following questions :

$10 \times 3 = 30$

- (a) (i) How the third component of isospin of a nucleus related to its mass number and atomic number? Give an example of isospin triplet nuclei.  
 (ii) Ground state of deuteron nucleus is an admixture of  ${}^3_1S$  and  ${}^3_1D$  states. What inference may be drawn about the nature of strong nuclear force from it?  
 (iii) Elucidate the contributions of surface energy, coulomb energy and asymmetry energy terms in semi empirical mass formula.  
 (v) Derive expressions for mass parabola and find the most stable nucleus for odd A isobar.

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- (b) (i) Explain how  $\beta$  disintegration energy for mirror nuclei provides a way for determining the nuclear radius parameter.  
 (ii) What are magic numbers? Why are they are so called? Cite two examples of doubly magic nuclei.  
 (iii) Nucleons moving independently in a harmonic oscillator potential possess eigenvalues  $E_{nl} = (\lambda + 3/2)\hbar\omega$ , where,  $\lambda=2n+l-2$  and  $n=1,2,\dots,\dots, l=0,1,2,\dots,\dots,n-1$ .  
 Find out the possible degenerate eigenstates for energy eigenvalues  $(7/2)\hbar\omega$   $(7/2)\hbar\omega$  and  $(11/2)\hbar\omega$  respectively.  
 (iv) State the relevant rules regarding shell model predictions about the ground state spin-parities of nuclei. Predict the ground state spin-parities of the following nuclei :  
 ${}^3_2\text{He}$ ,  ${}^7_3\text{Li}$ ,  ${}^{12}_6\text{C}$  and  ${}^{25}_{12}\text{Mg}$ .

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- (c) (i) Find the Q-values for the  $\beta^{\mp}$  and electron capture processes showing the reaction modes in the respective cases.  
 (ii) How can one differentiate between a neutrino and an anti-neutrino?  
 (iii) What do you mean by parity non conservation in beta decay? What is the does cause of such a non- conservation? Discuss briefly the experiment which demonstrates the non conservation of parity in beta decay.

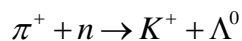
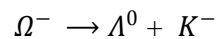
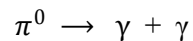
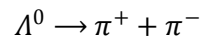
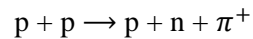
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- (d) (i) Draw a simple diagram of a Geiger-Muller (GM) counter and discuss briefly its principle of action. What is 'quenching effect' in the operation of a GM counter and how can it be achieved in such a counter?
- (ii) Show that in a two particle collision process, the total linear momentum in the Centre of Mass (CM) frame is zero. Establish the relationship between the scattering angles in CM frame and Laboratory frame.
- (iii) A  ${}^{14}_6\text{C}$  nucleus undergoes beta decay by producing the daughter nucleus  ${}^{14}_7\text{N}$ , a beta particle and an anti-neutrino. If the beta particle has the momentum  $\vec{p}$  and the daughter nucleus has the magnitude of momentum  $\frac{4p}{3}$  at angle of  $90^\circ$  to  $\vec{p}$ , what will be the magnitude and direction of the momentum of anti-neutrino?

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- (e) (i) Using generalized Gell-Mann- Nishijima formula, find the baryon numbers of the given particles :  $n$ ,  $\pi^-$ ,  $K^0$ ,  $\Sigma^+$ .
- (ii)  $\Omega^-$  particle is found to be a composite system of three s-quarks all in the ground state of the system. Discuss about its stability.
- Write down the quark compositions of  $\pi^+$ ,  $\bar{p}$ ,  $\bar{K}^0$  and  $\Delta^+$ .
- (iii) Draw the  $0^-$  meson octet in  $Y - I_3$  diagram. ( $Y$  is the hypercharge and  $I_3$  is the third component of isospin quantum number.
- (iv) Indicate the interactions responsible for the following reactions :



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**OR**

**B. Sc. Semester VI (Honours) Examination, 2020 (CBCS)****Subject: Physics****Paper: DSE-3 (Biophysics)**

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**Group-A**

Answer any six (6) questions:

6×5=30

1. What is monomer and polymer? Give examples. What is the importance of large biological molecule in a living system? 5
2. Write a short note on, (i) Dehydration synthesis and, (ii) Phospholipids. 5
3. Briefly discuss about the major types of RNA. 5
4. Write down the cellular function of proteins in case of a living system. 5
5. Define a biological neural network and its components. 5
6. Briefly describe the main differences between RNA and DNA. Write down the utility of a synthetic biological circuit. 5
7. What is genotype and phenotype? Give examples. Write down the importance of genotype-phenotype. 5
8. Define cell diffusion process (through cell wall) in light of statistical random walk model. 5

P. T. O.

**Group-B**

Answer any three (3) questions:

3×10=30

1. Describe nucleic acid and specify its roll in a living organism. What are nucleotides and nitrogenous bases? How protein biosynthesis is associated with nucleic acids? 3+4+3
2. What do you mean by genetic circuits? Briefly describe logic AND gate, logic OR gate and logic NAND gate in terms of synthetic biological circuits. 3+7
3. What is a neural network? Describe the working process of an artificial neural network with diagrams and explain a three layer neural network. 3+7
4. Describe the simple isotropic random walk model (one dimensional) in a biological system and hence derive the probability distribution function and mean square displacement. 4+3+3
5. What is molecular evolution process in case of a living system? Briefly describe the genetic mutation process. Write short notes on genetic recombination process and genetic drift. 3+3+4