

## U.G. 6th Semester Examination - 2021

### PHYSICS

Course Code : BPHSDSHT4

Course Title : Nuclear and Particle Physics

Full Marks : 40

Time : 2 Hours

*The figures in the right-hand margin indicate marks.*

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

1. Answer any **ten** questions: 1×10=10
- a) The binding energy per nucleon is maximum for the nucleus
- i)  $^{56}\text{Fe}$ ,                      ii)  $^4\text{He}$ ,  
 iii)  $^{208}\text{Pb}$ ,                      iv)  $^{101}\text{Mo}$ .
- b) What are the possible eigen values of a Parity operator?
- c) The deviation of the charge distribution of a nucleus from spherical symmetry can be estimated by measuring its
- i) Electric charge,  
 ii) electric dipole moment  
 iii) magnetic dipole moment  
 iv) electric quadrupole moment

- d) In the Rutherford's scattering experiment, the number of  $\alpha$  particles  $N$  scattered at a scattering angle  $\phi$  is related to its initial kinetic energy as

i)  $N\alpha(\text{KE})^2$                       ii)  $N\alpha(\text{KE})$

iii)  $N\alpha(\text{KE})^{-2}$                       iv)  $N\alpha(\text{KE})^{-1}$

- e) Which quantum mechanical phenomenon is responsible for alpha emission from nucleus?
- f) The relation between the charge operator  $Q$  and the third component of isospin operator  $\hat{\tau}_3$  of a nucleon is

i)  $\hat{Q} = \frac{|e|}{2}(1 - \hat{\tau}_3)$                       ii)  $\hat{Q} = \frac{|e|}{2}(1 + \hat{\tau}_3)$

iii)  $\hat{Q} = \frac{|e|}{4}(1 + \hat{\tau}_3)$                       iv)  $\hat{Q} = \frac{|e|}{4}(1 - \hat{\tau}_3)$

- g) Write down the basic reaction equation for beta decay.
- h) Classify the following particles in terms of its spins (Bosons/Fermions): electron, proton, neutron, photon.

i) The quantum mechanical probability T for barrier transmission of an  $\alpha$  particle is given by-

- i)  $e^{-k_2 a}$                       ii)  $e^{-2k_2 a}$   
iii)  $e^{2k_2 a}$                       iv)  $e^{k_2 a}$

where  $k_2 = \sqrt{2m(V-E)/\hbar}$ ,  $m$ = mass of  $\alpha$  particle,  $V$ = potential barrier,  $a$ = width of the potential barrier and  $E$ = energy of  $\alpha$  particle.

j) According to Yukawa, which particle is responsible for nuclear force between nucleons?

k) The experimental value of the intrinsic quadrupole moment of  ${}_{71}^{123}\text{Lu}$  nucleus is  $Q_0 = -8 \text{ barns}$ , which suggests that the shape of this nucleus is

- i) spherical,                      ii) cubical  
iii) prolate spheroid      iv) oblate spheroid

l) Write down the quark content of proton and neutron.

m) The radii of muonic orbits are smaller than the electronic orbits by the factor

- i) 1/100                      ii) 1/200  
iii) 1/207                      iv) 1/210

n) State whether the following statement is true or false: 'photon doesn't have an electric charge, but gluons have color.'

o) Which term in semi-empirical mass formula can be explained by Fermi gas model ?

2. Answer any **five** questions:                       $2 \times 5 = 10$

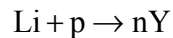
- a) Define binding energy of a nucleus.  
b) With the help of uncertainty principle show that electrons cannot reside inside nucleus.  
c) The half-life of a radio-active substance is 5 hours. At what time it will be reduced to 1/3?  
d) Write down some main features of nuclear force.  
e) What is Cherenkov radiation?  
f) Write down the Bethe-Block formula of energy loss of a charged particle, explaining all the terms.  
g) Show that neutrino and anti-neutrino are two different particles.  
h) Why cyclotron is not used to accelerate electron?

Answer any **two** questions:  $5 \times 2 = 10$

3. a) What fraction of beam of 7.7 MeV  $\alpha$  particles incident upon a gold foil of  $3.7 \times 10^{-7}$  thick would be scattered by less than  $1^\circ$ ?  
b) Show that  $\beta^+$  decay is possible if the mass of the parent atom is greater than the mass of the daughter atom by at least twice the electronic mass.  $3+2$

4. Using semi empirical mass formula show that for stable nucleus Atomic 1 A number,  $z = \frac{1}{2}A$  (A=Mass Number).  $5$

5. Calculate the Q-value of the following reaction in **MeV**.



Given masses:  $M(\text{Li})=7.01822 \text{ u}$ ,  $M(\text{p})=1.00814 \text{ u}$ ,  $M(\text{n})=1.00898 \text{ u}$ ,  $M(\text{Y})=7.01915 \text{ u}$ .

Is the reaction exoergic or endoergic? What is the threshold energy of this reaction?  $2+1+2$

Answer any **one** question:  $10 \times 1 = 10$

6. a) State the experimental observations that support nuclear shell structure? Write down the terms of the potential that can explain the observed shell structure of nucleus?  $3+2$

- b) Make a comparison chart among the fundamental interactions in terms of strength, range, force carrier, particles they affect and interaction time.  $5$

7. a) What are the characteristics of nuclear force?  
b) If  $m_x$ ,  $M_x$  and  $Q$  be the mass of the projectile, the target nucleus and the Q-value of the reaction then show that threshold energy of

$$\text{the reaction is } E_{\text{th}} = -Q \left( 1 + \frac{m_x}{M_x} \right). \quad 5+5$$

8. Mention the name of all the quarks and leptons with symbols. State the relation between electric charge and hypercharge of a particle. What are the quark structure of baryons and mesons? What are the resultant isospin of  $I_1 = 1$  and  $I_2 = \frac{1}{2}$ ? Which conservation law is violated in the following reaction:



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