No. of Printed Pages : 8 **MPH–017**

M. SC. (PHYSICS)

(MSCPH)

Term-End Examination

June, 2026

MPH-017 : NUCLEAR AND PARTICLE PHYSICS

Time : 2 Hours *Maximum Marks : 50*

Note : *Answer any* ***five*** *questions. Marks are indicated against each question. You may use a calculator. Symbols have their usual meanings. The values of physical constants are given at the end.*

1. (a) Using the semi-empirical mass formula, calculate the binding energy and the Coulomb energy for ${}^{23}_{11}\mathrm{Na}$ and ${}^{209}_{83}\mathrm{Bi}$.

Given the constants :

$a_v = 15.5$ MeV, $a_s = 16.8$ MeV

$a_c = 0.691$ MeV, $a_{sym} = 23$ MeV

$a_p = 34$ MeV 6

(b) Plot and explain the variation of binding energy per nucleon as a function of mass number. 4

2. (a) Consider a sphere of radius R with a constant nuclear charge density given by

$$\rho(r) = \begin{cases} \rho_0 & r \le R \\ 0 & r > R \end{cases}$$

Normalize the charge density and then estimate the mean square radius of the sphere. Also, using above result, estimate the charge form factor. 7

(b) Write a short note on parity. 3

3. (a) Assuming that the wave function of the deuteron for the ground state is

$u(r) = Ce^{-\alpha r}$ for $0 \leq r \leq \infty$ with $\alpha = 0.232 \text{ fm}^{-1}$.

(i) Obtain the mean square radius of separation between neutron and proton.

(ii) Estimate the average radius of deuteron $< r >$. 5

(b) The experimentally observed magnetic dipole moment of deuteron (μ_d) is $0.8574\ \mu_N$. Write the possible spin configuration of neutron and proton on the basis of observed values of dipole moment. Given :

$\mu_p = 2.793\ \mu_N$ and $\mu_n = -1.913\ \mu_N$ 5

4. Evaluate the n-p scattering cross-section of low energy neutrons (in zero-energy limit) with relative energy E (= $E_n/2$, where E_n is neutron laboratory energy), using the concept of Fermi scattering length. The form of square well nuclear potential is given by

$$V(r) = \begin{cases} -V_0 & \text{if } r \leq r_0 \\ 0 & \text{if } r > r_0 \end{cases}$$

where r_0 is the range of square well potential. Also use zero range approximation in the calculations. 10

5. (a) Write the Geiger and Nuttal law. If the range in standard air of the α-particles from sodium (half-life $T_{1/2}$ = 1622 yrs.) is 3.36 cm, whereas from polonium ($T_{1/2}$ = 138 days), this range is 3.85 cm. Calculate the value of a and b and write the expression of Geiger-Nuttal law. 6

(b) What are the possible multipolarities of the γ-rays emitted in the transitions between the levels 3^- and 1^- ? 4

6. (a) What are endoergic and exoergic nuclear reactions ? Calculate the Q value of the following reaction :

$$^{76}_{34}\mathrm{Se}(\alpha, 2n)\ ^{78}_{36}\mathrm{Kr}$$

and state whether the reaction is endoergic or exoergic reaction. Given the following atomic masses :

$m\left(^{76}_{34}\mathrm{Se}\right) = 75.91921\mathrm{u}$;

$m\left(^{78}_{36}\mathrm{Kr}\right) = 77.92037\mathrm{u}$;

$m\left(^{4}_{2}\mathrm{He}\right) = 4.0026\mathrm{u}$ and $m(n) = 1.00866\mathrm{u}$.

5

(b) A compound nucleus has a neutron resonance at 65 eV which is produced through a neutron entrance channel. The resonance state mainly decays through a neutron, gamma and alpha channel with the partial decay widths as $\Gamma n = 4.2$ eV, $\Gamma r = 1.3\,\text{eV}$ and $\Gamma\alpha = 2.7\,\text{eV}$ respectively. Estimate the (n, r) cross-section. 5

7. (a) What are the four fundamental forces in nature ? List the field particles that mediate the electromagnetic, weak and strong interactions and the properties of these particles. Which of the fundamental forces (interactions) are responsible for the neutrino flux from the sun and the neutrinos produced in a reactor ? 5

(b) Ω baryon is produced in the following strong reaction :

$$k^- + p \rightarrow \Omega^- + k^+ + k^o$$

what is the strangeness of Ω^- ?

In one of the weak decays of Ω^- :

$$\Omega^- \rightarrow \cong^o + \pi^-$$

What is the strangeness $\cong^o$? 5

8. (a) State the values of I and I_3 for the π^- meson and its quark content. Determine the wave function for π^- and π^o. 5

(b) Consider k mesons of mass m_k decaying into two pions of mass m_π, each in the laboratory frame. Show that the energy of each pion is equal to $m_k/2$ and the momenta are $p_\pi = \frac{1}{2}\sqrt{m_k^2 - 4m\pi^2}$. 5

Physical Constants :

$1\,\text{u} = 931.5\ \text{MeV}/c^2$

$1\,\text{eV} = 1.6 \times 10^{-19}\,\text{J}$

$h = 6.626 \times 10^{-34}\,\text{Js}$

$\hbar = 1.054 \times 10^{-34}\,\text{Js}$

$c = 3 \times 10^{8}\,\text{ms}^{-1}$

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