No. of Printed Pages : 7 **MPH–017**

M. SC. (PHYSICS)

(MSCPH)

Term-End Examination

June, 2025

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) Obtain the mass defect for $^{16}_{8}\mathrm{O}$ and the proton and neutron separation energies. 5

Given :

$$m(^{16}_{8}\mathrm{O}) = 15.9949\,\mathrm{u}$$

$$m(^{15}_{7}\mathrm{N}) = 15.00011\,\mathrm{u}$$

$$m(^{15}_{8}\mathrm{O}) = 15.00307\,\mathrm{u}$$

$$m_p = 1.0078\,\mathrm{u}$$

$$m_n = 1.00866\,\mathrm{u}$$

(b) A human body contains 0.0250 kg of normal potassium of which 0.012 percent is the radioactive beta emitter potassium-40. The half-life of potassium-40 is 1.3×10^{9} years. Calculate the rate of production of β-particles in the body from the decay of potassium-40. 5

2. (a) For the nuclear charge density $\rho_{ch}(r) = \rho_0\, e^{-q_0 r}$, where ρ_0 and q_0 are constants, compute the charge form factor and the mean square charge radius $<r^2>$. You may use

$$\Gamma_{n+1}(x) = \int_0^{\infty} x^n e^{-x}\, dx = n!$$ 5

(b) Estimate the nuclear radii for ^{15}N and ^{11}B from the electron scattering experiment using an electron beam of energy 400 MeV, when the first minimum was observed at 45° and 60°, respectively. 5

3. (a) Explain and justify the observed deviations in magnetic dipole moment and quadrupole moment of deuteron. 5

(b) Consider a square well potential :

$$V(r) = \begin{cases} -V_0, & r \le r_0 \\ 0 \ , & r > r_0 \end{cases}$$

Obtain the general form of the wave function of deuteron within the range of potential and outside. 5

4. (a) The scattering cross-section is given as :

$$\sigma_{sc} = \frac{4\pi}{k^2} \sum_l (2l+1) \sin^2 \delta_l$$

where k is the wave number and δ_l is the phase shift. Show that the scattering cross-section in zero-energy limit is given by $\sigma = 4\pi a^2$, where a is the Fermi scattering length. 5

(b) Using the effective range formula, evaluate the total *n-p* scattering cross-section for a neutron interacting with a free proton in laboratory at 6 MeV. 5

Given :

Scattering lengths :

$$a_t = 5\,\text{fm},\ a_s = -21\,\text{fm},$$

Effective range :

$$r_{ot} = 2\,\text{fm},\ r_{os} = 2.5\,\text{fm}$$

You may use the mass of the nucleon $Mc^2 = 938\ \text{MeV}$.

5. (a) Using Bethe-Weizsacker's mass formula, the condition of stability of a nucleus of mass A with Z_0 protons is given by :

$$Z_0 = \frac{A}{2 + 0.015 A^{2/3}}$$

For the value of A = 135, estimate the value of Z_0. What kind of decay would occur for $Z < Z_0$ and $Z > Z_0$? 5

(b) On the basis of semi-empirical mass formula, explain why there are two mass parabolas for even-A nuclei and only one for A-odd nuclei. 5

6. (a) Using the nuclear shell model, obtain the magnetic moment for the ground state of $^{41}_{20}Ca$ and $^{41}_{21}Sc$ nuclei. 6

Given :

$$(g_l)_p = 1; (g_s)_p = +5.58$$

and $$(g_l)_n = 1; (g_s)_n = -3.82$$

(b) Explain the process of α and γ decays with one example of each. 4

7. (a) Explain why it was necessary to assign a quantum number 'strangeness' to particles. What are the selection rules for strangeness ? 5

(b) What are weak interactions ? Assuming that a hypothetical weak interaction has a range of 1 μm, calculate the mass of the particle mediating this interaction (in eV). 5

8. List the quantum numbers B, J, I, I_3, S and Q for the quarks *u*, *d*, *s*. What is the relation connecting Q with I_3, B and S ? State the quark content for *p* and *n*. 6+2+2

Physical Constants :

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

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

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

$\hbar_c = 197\ \text{MeV fm}$

$1\,\text{fm} = 10^{-15}\,\text{m}$

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

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

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