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PHYSICS - Optional

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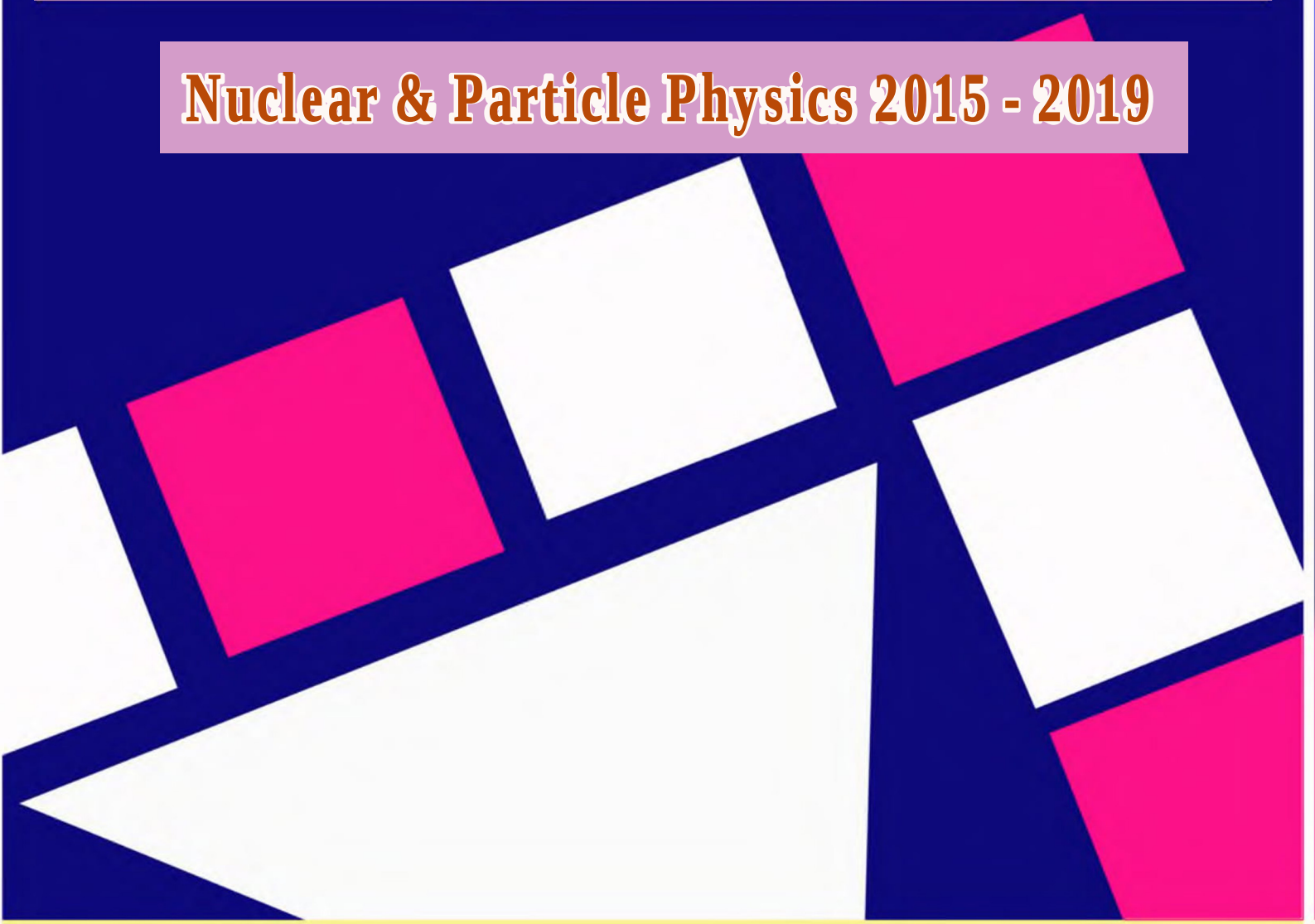
Nuclear & Particle Physics 2015 - 2019



UPSC – PHYSICS Optional – 2015 Questions

1. Define Q of a reaction. Calculate the Q-value of the reaction :

$^{9}_{4}\mathrm{Be}\left(^{4}_{2}\mathrm{He},\mathrm{n}\right)^{12}_{6}\mathrm{C}$.

Given : Mass $(9_{Be}) = 9.012183$ u

Mass $(4_{He}) = 4.002603$ u

Mass $(12_{\mathrm{C}}) = 12.000$ u **[10M]**

2. State the quantum numbers I_2, Y and S for uds quarks and antiquarks. Which combination of these leads to the formation of a (i) proton and (ii) neutron ? **[10M]**

3. Describe grand unification theories (GUT). **[20M]**

4. How many types of neutrinos exist ? How do they differ in their masses ? **[15M]**

5. Write down the following decays in terms of quarks:

(i) $\Omega^- \rightarrow \Lambda^\circ + K^-$

(ii) $\Lambda^\circ \rightarrow p + \pi^-$

(ii) $K^- \rightarrow \mu^- + v_\mu$. **[15M]**

UPSC – PHYSICS Optional – 2016 Questions

1. Explain why the deuteron has no excited state. **[10M]**

2. What are elementary particles and how are they classified? Describe in brief the different types of interactions that can occur between the elementary particles. **[10M]**

3. State the basic assumption of single particle shell model. How do the centrifugal and spin-orbit terms remove the degeneracy of a three-dimensional spherical harmonic oscillator ?

[25M]

4. Show that in the nuclear shell model, the level spacing between major oscillator shells is approximately $h\omega = 41A^{-1/3}$ MeV. **[15M]**

5. Predict the spin and parity of ground states of the following nuclei on the basis of shell model : **[10M]**

(i) $8^{O^{15}}$

(ii) $8^{O^{16}}$

(iii) $17^{Cl^{38}}$

6. Explain the various leptonic family members. What is leptonic number conservation? Based on this law, state whether the following reactions are possible or not: **[25M]**

(i) $\pi^- \rightarrow \mu^- + \bar{\nu}_\tau$

(ii) $n \rightarrow p^+ + e^- + \bar{\nu}_e$

7. Write down the mark structure of the following hadrons : **[15M]**

$\Delta^{**}, \Omega^-, \Sigma^-$ and $\wedge^\circ$

Write down the following decays in terms of quarks:

(i) $n \rightarrow p^* + e^- + \bar{\nu}_e$

(ii) $\Delta^* \rightarrow \pi^* + n$

(ii) $\Sigma^* \rightarrow p^* + \pi^0$

8. Explain unification of electromagnetic and weak interactions. What is Z-boson ? What is its relevance in electroweak unification ? **[10M]**

UPSC – PHYSICS Optional – 2017 Questions

1. Estimate the order of nuclear radius of lead $(Z = 82)$ using the large angle (back) scattering of alpha particles of energy 10 MeV incident on a target (lead).

[Given : $(4\pi\epsilon_0)^{-1} = 9 \times 10^9 Nm^2C^{-2}$] **[10M]**

2. Distinguish between charge independence and charge symmetry of nuclear force. Give one example for each of these . **[10M]**

3. Describe briefly how parity violation in β-decay was experimentally observed? What do you understand by the statement, 'neutrinos are left-handed' ? **[10M]**

4. (i) Write two properties of deuteron which support the existence of non-central tensor force.

(ii) Given that the deuteron magnetic moment operator (in units of nuclear magneton) can be expressed as $\mu_d = \mu_n\vec{\sigma}_n + \mu_p\vec{\sigma}_p + \frac{1}{2}l,$.

Where $\vec{l}$ is the relative angular momentum between neutron and proton, $\vec{\sigma}_n \; and \; \vec{\sigma}_p$ are the Pauli spin operators and μ_n and μ_p are the respective magnetic moments. Find out the D-state probability of deuteron wave function.

[Given: $\mu_d = 0.857\ \mu_N$, $\mu_n = -1.913\ \mu_N$ and $\mu_p = 2.793\ \mu_N$; μ_N (nuclear magneton)]

[15M]

5. (i) How does one explain the approximate constancy of average binding energy per nucleon (BE/A) of nuclei in the region $30 \leq A \leq 170$ in the plot of BE/A versus mass number A ?

(ii) Write the semi-empirical mass formula pointing out the role of volume term, surface energy term, coulomb and symmetry energy correction terms. **[15M]**

6. (i) State the three characteristic properties of strong, weak and electromagnetic forces distinguishing one from the other.

(ii) Point out the interactions in which the following conservation laws are obeyed or violated

(a) Isotopic spin

(b) Hyper charge

(c) Lepton number

(d) Charge conjugation

(iii) Write down the quark constituents of each of the following :

$(a)\ \pi^+, \quad (b)K^+\ (c)\Delta^{++},\ (d)\Sigma^0, (e)\Omega^-$ **[20M]**

UPSC – PHYSICS Optional – 2018 Questions

1. Nuclear forces are mediated by exchange of $\pi - mesons$ of rest mass 140 MeV. Estimate the range of nuclear forces. **[10M]**

2. The maximum energy of a positron (e^+) released in the decay of $6^{C^{13}}$ atom into a $7^{N^{13}}$ atom is 1.202 MeV. If the mass of the $6^{C^{13}}$ atom is 13.003354 u, calculate the mass of the $7^{N^{13}}$ atom. **[10M]**

3. Which of the following elementary particle reactions / decays are allowed under various conservation laws? If allowed, write down the type of interaction and the characteristic time by which it would proceed: **[10M]**

(i) $p + n \rightarrow \Lambda^0 + \Sigma^+$

(ii) $\pi^+ + n \rightarrow \Lambda^0 + \mathrm{K}^+$

(iii) $P + n \rightarrow\ \mathrm{K}^+ + \Sigma^+$

(iv) $\pi^0 \rightarrow \gamma + \gamma$

(v) $\bar{n} \rightarrow \bar{p} + e^+ + v_e$

4. Assuming that the neutron – proton interaction has a square well form

$$V(r) = -V_0 \quad \text{for } r \leq b$$

$$= 0 \quad \text{for } r > b$$

The ground state wave function of deuteron nucleus is given as

$$\varphi(r) = A \sin kr \quad \text{for } r \leq b$$

$$= Ce^{-\gamma r} \quad \text{for } r > b$$

Where $k = \sqrt{\frac{M}{h^2}(V_0 + W)}$ and $\gamma = \sqrt{\frac{MW}{h^2}}$

Here M is the nucleon mass, W is the binding energy of deuteron and A and C are constants.

(i) Show that for a just bound state of deuteron **[10M]**

$$V_0 b^2 = \frac{\pi^2 h^2}{4M}$$

(ii) Explain why deuteron is a loosely bound extended structure. **[10M]**

5. A π^- − meson at rest decays into a μ^- meson :

$$\pi^- \rightarrow \mu^- + \bar{v}_\mu$$

Calculate the kinetic energy of the μ^- meson emitted in the reaction. **[15M]**

6. Write the semi-empirical mass formula for nuclei and on its basis draw mass parabolas for odd and even isobars. What would be the most stable isobar in each case? **[15M]**

7. Obtain an expression for the magnetic moment of a nucleus having one nucleon outside the closed core. Use this to calculate the magnetic moment of $8^{O^{17}}$ nucleus. **[20M]**

UPSC – PHYSICS Optional – 2019 Questions

1. Stable light nuclei have equal number of protons and neutrons, whereas heavy nuclei have excess of neutrons. Explain why. [**10M]**

2. Assuming equal masses for up (u) and down (d) quarks, find the ratio (μ_n/μ_p) of the magnetic moments of neutron and proton. [**10M]**

3. Explain the various methods of finding the size of the nucleus. How will you determine the nuclear radius from the observation of beta rays resulting from nuclear transition when the initial and final nuclei are mirror nuclei? **[20M]**

4. Given that the single particle energy separation between $1d_{5/2}$ *and* $1d_{3/2}$ in 17_O is 5 MeV. Calculate the strength of spin-orbit interaction. It is observed that $1d_{5/2}$ level is lower than $1d_{3/2}$ level. **[15M]**

5. Why is it not possible to detect the parity violation in weak interaction by observing only the beta rate? Justify your answer **[15M]**

6. (i) Explain the origin of the nuclear magnetic moment. Deduce expression for the magnetic dipole moment with the help of the Schmidt single particle model.
(ii) For a system consisting of one proton and one neutron (not necessarily a deuteron), write down the various possible states specifying clearly its isospin, spin and orbital quantum numbers. **[20M]**