Tutorial 2:

- Ground state of deuteron,
- magnetic moment and non-central forces;
- Meson theory of nuclear forces;
- Salient features of nuclear forces;

Q1:

(i) What are salient features of nuclear forces ? 10

(ii) Discuss Yukawa's theory of nuclear forces. 10

2014

Q2:

Explain why the deuteron has no excited state. *10*

2016

Q3:

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

(ii) Given that the deutron magnetic moment operator (in units of nuclear magneton) can be expressed as

$$\vec{\mu}_d = \mu_n \vec{\sigma}_n + \mu_p \vec{\sigma}_p + \frac{1}{2} \vec{l},$$

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 deutron wave function.

[Given : $\mu_d = 0{\cdot}857\ \mu_N$, $\mu_n = -1{\cdot}913\ \mu_N$ and $\mu_p = 2{\cdot}793\ \mu_N$; μ_N (nuclear magneton)] 5+10=15

2017

Q4:

Distinguish between charge independence and charge symmetry of nuclear force. Give one example for each of these. 10

2017

Q5:

Assuming that the neutron-proton interaction has a square well form

$$V(r) = -V_0 \quad \text{for} \quad r \le b$$
$$= 0 \quad \text{for} \quad r > b$$

the ground state wave function of deuteron nucleus is given as

$$\psi(r) = A \sin kr \quad \text{for} \quad r \le b$$
$$= Ce^{-\gamma r} \quad \text{for} \quad r > b$$

where $k = \sqrt{\frac{M}{\hbar^2}(V_0 + W)}$ and $\gamma = \sqrt{\frac{MW}{\hbar^2}}$.

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

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

10

(ii) Explain why deuteron is a loosely bound extended structure. 10

2018

Q6:

Nuclear forces are mediated by exchange of π-mesons of rest mass 140 MeV. Estimate the range of nuclear forces. 10

2018

Q7:

In a certain cyclotron, the maximum radius that the path of a deuteron may have before it is deflected out of the magnetic field is 20 cm.

(i) Calculate the velocity of the deuteron at this radius.

(ii) What is the energy of deuteron in MeV?

Given, magnetic field = 1500 gauss and mass of deuteron = $3{\cdot}34 \times 10^{-27}$ kg. 10

2020

Q8:

Calculate in terms of the nuclear magneton, μ_N, the magnetic dipole moment of $^3S_1$ state of deuteron. Given, $\mu_p = 2{\cdot}792847\mu_N$ and $\mu_n = -1{\cdot}913042\mu_N$. 15

2020

Q9:

What is the importance of study of deuteron ? Obtain the solution of Schrödinger equation for ground state of deuteron and show that deuteron is a loosely bound system. 20

2021

Q10:

If the nuclear force is charge independent and a neutron and proton form a bound state then why is there no bound state for two neutrons ? What information does this provide on the nucleon-nucleon force ? 10

2022

Q11:

What do you understand by nuclear forces ? Explain meson theory of exchange forces. 5+10=15

2023

Q12.

For the ground state of deuteron, prove that the radius of nucleon is of the order of $\sim 2{\cdot}15 \times 10^{-13}$ cm. *10*

2024

Q13.

Show that the energy of the triplet state ($S = 1$) is not equal to the energy of the singlet state ($S = 0$). 10

2025

Q14.

ρ^0 and K^0 mesons both decay mostly to π^+ and π^-. Why the mean lifetime of ρ^0 is 10^{-23} s, whereas that of K^0 is $0{\cdot}89 \times 10^{-10}$ s? 10

2025