Exam. Code : 209003
Subject Code : 3766

M.Sc. (Physics) 3rd Semester

PHY–504 : NUCLEAR PHYSICS

Time Allowed—3 Hours] [Maximum Marks—100

Note :— Section A is compulsory. Attempt **ONE** question each from Sections B, C, D and E. All questions carry equal marks.

SECTION—A

1. (a) A neutron-proton system can form a bound state while a neutron-neutron or a proton-proton system does not. Even though the nuclear forces are charge independent. Why does this happen ?

   (b) In the β-decay, if a $\frac{3^+}{2}$ nuclear state decays by a first-forbidden transition. What will be the possible spin-parity state for the final nuclei ?

   (c) The ground state spin-parity of $^{26}_{13}Al$ is 5^+. Justify its spin and parity based on single-particle shell model.

   (d) When a particle is moving with velocity $\vec{v}$, which of the following quantities are conserved ? Energy (E), parity ($\hat{p}$), components of angular momentum (L_x, L_y, L_z) and L^2 :
   (i) In the static central field
   (ii) In the static uniform field along the z-direction.

   (e) Calculate the differential and total cross-section of a particle by a central potential with phase shift 30°. Estimate the relative contribution of p-wave to the total cross-section when phase shift is 2°.

   (f) Calculate the magnetic dipole moment of following nuclei :
   (i) $^{39}_{20}Ca$
   (ii) $^{41}_{21}Sc$

   (g) The ground state spin-parity of $^{14}_{7}N$ is 1^+. What will be the isospin (T) value of this state ? What will be the ground state spin-parity of the isobaric analog state partner of $^{14}_{7}N$? Identify them.

   (h) What is the difference between coherent and incoherent scattering ? For neutron scattering by the hydrogen-molecule (separation between protons 10^{-8} cm), if the energy of incident neutron 100 keV, will this scattering be coherent or incoherent ?

   (i) What was the discrepancy in the observed vs. theoretical scattering cross-section in the low-energy elastic scattering of neutron by a free proton ? How can this discrepancy be resolved ?

   (j) What is the physical significance of scattering length ? How can the total cross-section be written in terms of the scattering length ?

SECTION—B

2. (a) Define the ground state of deuteron. If a neutron interact with the nucleus, then define its various states including ground state.

   (b) Evaluate the deuteron magnetic dipole moment and hence show that the probability of existence of deuteron in D-State is just 4%.

3. (a) Obtain the scattering cross-sections for the singlet and triplet spin states by using the neutron beam on ortho- and para-hydrogen molecules.

   (b) Consider a nucleon-nucleon potential of the form

$$V = -V_0 \left[a + b\vec{\sigma}_1 \cdot \vec{\sigma}_2\right] f(r)$$

   where r is the relative distance of two nucleons. Find the strengths of this potential in singlet and triplet states.

SECTION—C

4. (a) What are the limitations of liquid-drop model ? How would these be resolved in single-particle shell model ? Also draw its complete level diagram.

   (b) The neutron and proton separation energies of $^{40}_{20}$ Ca are 15.6351 and 8.3282 MeV, respectively. Estimate the radius of the nucleus assuming that the particle is removed from its surface.

5. (a) How do vibrational spectra arise in nuclei ? Give a complete model which will be best suited for these spectra.

   (b) The observed nuclear moments of $^{209}_{83}$Bi are $I = \frac{9}{2}\hbar$; $\mu = 4.1\ \mu_N$ and $Q = -0.4 \times 10^{-28} m^2$. Determine the expected values for these moments using the shell model and comment on any significant differences.

SECTION—D

6. Examine critically the different physical processes resulting from the interaction of γ-rays with matter and the relative importance of these processes at different energies of radiation.

7. (a) Which of the following is Fermi, Gamow-Teller or mixed transitions (in case of forbidden, mention the degree of forbidden-ness) :

   (i) $^{14}_{8}O(0^+) \rightarrow {}^{14}_{7}N^*(0^+)$

   (ii) $^{40}_{19}K(4^-) \rightarrow {}^{40}_{20}Ca(0^+)$

   (b) Which hypothesis was given to explain the continuous β-decay spectrum ? Describe the Fermi theory of β-decay.

SECTION—E

8. Describe the conditions for direct nuclear reaction to occur and its reaction cross-section.

9. Explain in detail nuclear resonance scattering and hence obtain its cross-section.