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Roll No. -1513410

This question paper contains 2 printed pages.

M. Sc. (Physics & Astrophysics) Semester-I Examination November 2015

Nuclear & Particle Physics (PHYS. 404)

Time : 3 Hours *Maximum Marks : 70*

(Write your Roll No. on the top immediately on receipt of this question paper)

Attempt *All* Questions.

Symbols have their usual meanings.

1. Attempt all *Six* parts. **[marks: 6×3=18]**

(i) Considering that the ground state of deuteron is an admixture of $l = 0$ and $l = 2$ states, find the percentage contribution of $l = 2$ state. [$\mu_d(l = 0) = 0.87\ \mu_N$ and $\mu_d(l = 2) = 0.31\ \mu_N$, $\mu_z(deuteron) = 0.85\ \mu_N$].

(ii) The nucleus $^{21}_{11}Na$ is more massive than its "mirror partner" $^{21}_{10}Ne$ by 4.02 MeV/c^2. What is the difference between their Coulomb energies? Use this to estimate a value of the nuclear radius R. (The neutron-proton mass difference is 1.29 MeV/c^2.)

(iii) An incident neutron of 500 keV is scattered by hydrogen molecule (atomic separation ~ 10^{-8} cm). Find out if the scattering is coherent or incoherent.

(iv) Discuss the importance of spin-orbit interaction in the origin of magic numbers in the nuclei. Calculate the energy difference in the levels corresponding to same value of l introduced due to spin-orbit interaction.

(v) A pion at rest decays into a muon plus a neutrino. Determine the speed of the muon.

(vi) An electron of 100 MeV energy strikes a lead (^{207}Pb) nucleus.

(a) Compute the maximum possible momentum transfer.

(b) Compute the recoil energy given to the lead ^{207}Pb nucleus under the condition of part (a).

mass of π = 140 MeV/c^2 , mass of μ = 105 MeV/c^2

2. (a) How was the observed continuous energy spectrum of electron in the beta-decay explained? Draw the rough experimental energy distribution plots of the decay of β^+ & β^- of ^{64}Cu. Give an explanation for the observed difference between the distributions. Which additional factor takes care of the above behavior in the modified theoretical energy/momentum distribution obtained using Fermi theory?

(b) Assuming that the β-*decay* energy spectrum is given by

$$N(E)dE \propto \sqrt{E}\,(E_{max} - E)^2$$

Show that the most probable energy occurs at $E = E_{max}/5$.

(c) The $^{191}_{76}Os$ nucleus undergoes β^- *decay* to the excited state, at 171 keV, of $^{191}_{77}Ir$. Calculate the maximum K.E. of the β particle. [$M(^{191}_{76}Os) = 190.960920\ u$, $M(^{191}_{77}Ir) = 190.960584\ u$, $1u = 931.5\ MeV$].

(d) Using selection rules, classify the following *β-decays* (in case of forbidden transition, mention the degree of forbidden-ness):

(i) $^{26}Al(5^+) \rightarrow {}^{26}Mg(2^+)$ (ii) $^{131}I\left(\frac{7^+}{2}\right) \rightarrow {}^{131}Xe^*\left(\frac{7^+}{2}\right)$

(iii) $^{137}Cs\left(\frac{7^+}{2}\right) \rightarrow {}^{137}Ba^*\left(\frac{11^-}{2}\right)$ (iv) $^{40}K(4^-) \rightarrow {}^{40}Ar(0^+)$ **[4, 3, 2, 4]**

3. (a) Find the nuclear form factor for the spherically symmetric charge distribution

$$\rho(r) = \rho_o \frac{e^{-\frac{r}{a}}}{r}, \text{ where } \rho_o \text{ \& } a \text{ are constants.}$$

(b) The magnetic moment μ_z of a nucleus is given $\mu_z = (g_l l_z + g_s S_z)\mu_N$. Show that the μ_z of the odd-even nucleus with odd number of protons can be expressed as below:

$$\langle\mu_z\rangle = \mu_N\left\{A\,j + \frac{B\,j}{j+C}\right\};\ with\, j = l - 1/2$$

Determine the values of A, B & C in the above expression [Given: $g_l(p)=1$, $g_s(p)=5.6$].

(c) Using the extreme particle shell model, predict the ground state spin, parity and magnetic moment of the following nuclei: $^{16}_{8}O, {}^{41}_{20}Ca, {}^{64}_{29}Cu$. **[3,4,6]**

4. (a) Schematically draw the baryon $\left(J^P = \frac{1^+}{2}\right)$ octet indicating the strangeness, charge, isospin and the quark content of each baryon. What kind of mass relations one can derive?

(b) According to quark model predictions, calculate the mass of 0^- meson consisting of *u*-quark and *u*-antiquark if $A_s = (2m_u/\hbar)^2 160\ MeV/c^2$. Also, calculate the magnetic moments (in units of μ_N) of the bare *u*-quark and *u*-antiquark. [$m_u = 310\ MeV/c^2$, $m_p = 940\ MeV/c^2$].

(c) Comment if the following two reactions are possible or not. Give reasons to support your answer.

$$K^+ \rightarrow \pi^+ + \pi^+ + \pi^- \quad \& \quad K^+ \rightarrow \pi^+ + \pi^o$$

[6, 5, 2]

5. (a) Consider the production of hypothetical particle 'X' through the process:

$$e^+ + e^- \rightarrow X \quad (m_X = 124\ GeV/c^2)$$

Find the minimum energy of the electron beam needed to produce X, in the experiment where the electron and positron will collide each other with equal and opposite momentum. If such a particle is to be produced in a fixed target experiment with the beam of e^+ striking the target of e^- at rest, what is the required threshold e^+ beam energy?

(b) What are quark contents and charge of the following hadrons: Ξ_{cc}, Ω_c?

(c) Predict the missing particle in the following allowed transitions:

(i) $\_ + n \rightarrow p + e^-$ *(ii)* $\Omega^- \rightarrow \_ + \pi^-$

(iii) $\pi^- + p \rightarrow \Lambda + \_$ *(iv)* $\Sigma^0 \rightarrow \_ + \gamma$

[6, 3, 4]