UNIVERSITY OF RUHUNA
BACHELOR OF SCIENCE (SPECIAL) DEGREE LEVEL II (SEMESTER II)
EXAMINATION – AUGUST 2021

SUBJECT: PHYSICS
COURSE UNIT: PHY4084 **TIME: 02 hours & 30 minutes**

Part II

Answer FIVE (05) Questions only.

(All symbols have their usual meaning)

In the *nuclear shell model, orbitals* are filled in the order $1s_{\frac{1}{2}}, 1p_{\frac{3}{2}}, 1p_{\frac{1}{2}}, 1d_{\frac{5}{2}}, 2s_{\frac{1}{2}}, 1d_{\frac{3}{2}}, 1f_{\frac{7}{2}}, 2p_{\frac{3}{2}}, 1f_{\frac{5}{2}}$

1. (a) Obtain the threshold energy of the reaction ${}^{209}_{83}Bi(p,d)^{208}_{83}C$.
Masses of ${}^{209}_{83}Bi$, p, d, and ${}^{208}_{83}Bi$ in **u** are 208.980394, 1.007825, 2.014102, and 207.979731 respectively. **(08 marks)**

(b) ${}^{14}N(n,p)^{14}C$ shows resonance at 0.495, 0.639, 0.998, 1.120, 1.211 MeV. Find excited states of the compound nucleus.
Masses of ${}^{14}N$, ${}^{15}N$, ${}^{14}C$, n, and p in a.m.u are 14.007518, 15.004857, 14.007683, 1.008983, and 1.008144 respectively**.** **(08 marks)**

(c) The single-particle shell model energy difference between p-orbitals of the nucleus ${}^{87}_{50}Sn$ is 3 MeV. Find the energy difference between the states in its f orbitals.
(09 marks)

2. (a) In the harmonic oscillator shell model, the energy levels are given by

$$E_{nl} = \hbar\omega\left(2n + l + \frac{3}{2}\right) = \hbar\omega\left(N + \frac{3}{2}\right) \qquad N = 0,1,2,\cdots$$

where $N = 2n + l$.

Find the number of nucleons in each shell and the total number of particles (accumulating) for all levels up to N, permitted by Pauli's exclusion principle.
(07 marks)

(b) The magnetic moment μ_z of a nucleus is given by $\mu_z = (g_l l_z + g_s s_z)\mu_N$. Show that the magnetic moment of the odd-even nucleus with an odd number of protons is given by

$$< \mu_z > = \frac{\mathrm{j}}{\mathrm{j}+1}(j - 1.24)\mu_N \qquad \text{with } j = l - \tfrac{1}{2}.$$

Here $g_l(p) = 1$ and $g_s(p) = 5.6$. **(10 marks)**

(c) Estimate the value of magnetic moment for ${}^{15}_{7}N$ and ${}^{39}_{19}K$ in terms of μ_N. **(04 marks)**

(d) Using the single-particle shell model, predict the ground state spin and parity of the nuclei

(i). $^{43}_{20}Ca$

(ii). $^{93}_{41}Nb$ **(04 marks)**

3. (a) Obtain the Q equation of the reaction $X(a,b)Y$. **(09 marks)**

(b) Protons of energy 5 MeV scattering from $^{10}_{5}B$ at an angle of 45° show a peak in the energy spectrum of the scattered protons at an energy of 3.0 MeV.

(i) To what excitation energy of $^{10}_{5}B$ does this correspond? **(08 marks)**

(ii) What is the expected energy of the scattered protons if the scattering is elastic? **(08 marks)**

4. (a) Name the four types of Fundamental Interactions and the source of each interaction. Write down the carrier particles that mediate each type of interaction. **(10 marks)**

(b) The π^+ at rest decays to μ^+ and ν_μ. Using the energy and momentum conservation laws, show that momentum of neutrino, $p_\upsilon = \dfrac{\left(m_\pi^2 - m_\mu^2\right)c}{2m_\pi}$.

Compute the momentum of the neutrino particle using the values given below.

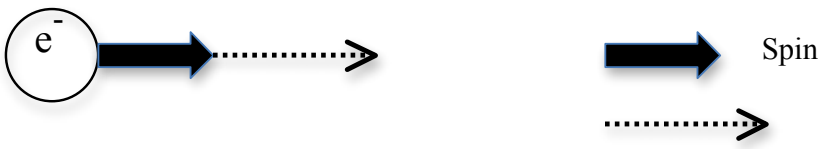
mass of the pion, $\mathrm{m}_\pi = 139\ \dfrac{\mathrm{MeV}}{\mathrm{c}^2}$

mass of the muon, $\mathrm{m}_\mu = 105\ \dfrac{\mathrm{MeV}}{\mathrm{c}^2}$.

Assume that neutrino is a massless particle. **(15 marks)**

5. (a) Define the Parity operator and Helicity. **(04 marks)**

(b) You are given the particle, electron below by representing its spin and motion.



(i) Draw the figure of the electron after the Parity operation. **(02 marks)**

(ii) Name those two electrons **(02 marks)**

(iii) Does it follow Parity conservation? **(02 marks)**

(c) Low energy collision s-wave scattering of pion π^+ with deuteron results in the production of two protons $\pi^+ + d \rightarrow p + p$.

(i) Write down the Parity of each particle separately. Give the reason for your answer. **(06 marks)**

(ii) Using Parity conservation of initial and final states, find the possible values for the orbital angular momentum of the final state. **(05 marks)**

(iii) Discuss what would be value for the relative orbital angular momentum of the resulting two proton system. **(04 marks)**

6. (a) What is meant by Feynman diagrams? **(02 marks)**

(b) Consider following two reactions.

$K^+ \rightarrow \pi^o + e^+ + \nu_e$

$\pi^+ + p \rightarrow \varepsilon^+ + K^+$

(i) Find out whether the above reactions are allowed under which interaction. **(08 marks)**

(ii) Write down each reaction in terms of quarks. **(05 marks)**

(iii) Describe each reaction in terms of Gauge Boson exchange using a suitable diagram. **(10 marks)**

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