10

(University of Choice)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

UNIVERSITY EXAMINATIONS
2021/2022 ACADEMIC YEAR

FIRST YEAR SECOND SEMESTER MAIN EXAMINATIONS

FOR THE DEGREE OF MASTER OF SCIENCE IN PHYSICS

COURSE CODE: **SPH 817**

COURSE TITLE: **NUCLEAR AND PARTICLE PHYSICS**

DATE: THURSDAY 28TH APRIL, 2022 **TIME:** 9:00 AM - 12:00 PM

INSTRUCTIONS TO CANDIDATES

TIME: 3 Hours

Answer any five questions. All questions carry equal marks (14mks)
Symbols used bear the usual meaning.

. MMUST observes ZERO tolerance to examination cheating

Assume where necessary:

Plank's constant	$h = 6.626 \times 10^{-34}$ Js
Charge on electron	$e = 1.602 \times 10^{-19}$ C
Speed of light	$c = 3.0 \times 10^{8}$ ms^{-1}
Atomic mass unit	$1u = 931.5\,MeV/c^{2}$
Number of atoms	$1\,mole = 6.023 \times 10^{23}$ $atoms$

QUESTION ONE (14 MARKS)

(a) The total Hamiltonian of a multi-electron atoms is $H = H_{CF} + H_{RES} + H_{SO}$, where H_{CF} is the central field Hamiltonian, H_{RES} is the residual Hamiltonian and H_{SO} the spin-orbit Hamiltonian. Using the two-electron atom illustrate the difference between L.S coupling and j.j coupling (5 marks)

(b) Calculate the possible values of L.S for L=1 and S=1/2. Illustrate the relative orientation of the three vectors **J**, **L** and **S** (5 marks)

(c) Determie the possible states of deuteron if its angular moment has quantum number J=1 (4 marks)

QUESTION TWO (14 MARKS)

(a) (i) Obtain an expression for the number of particles scattered from a beam of area A contains N_0 particles, after it transverses a thickness T of target material consisting of n scattering centre per unit volume each of cross-section area σ.

(3 marks)

(ii) For a hypothetical scattering target $10^{-3}\%$ of incoming neutron beam is scattered. If the target as a density of 1.06×10^{9} kg/m^{3}, mass number $A = 200$ and total neutron cross section per nucleus, $\sigma = 1.1\,barn$ find the target thickness.

(4 marks)

(b) In an experiment photon is incident on a proton rich paraffin target and a $^{14}_{7}N$ target. Determine the minimum photon energies required to produce the observed $5.7\,MeV$ recoil proton and the $1.4\,MeV$ recoil $^{14}_{7}N$ nuclei. (7 marks)

QUESTION THREE (14 MARKS)

(a) Consider the wave functions of the 2^3S level of Helium which are given in the cetral field approximation by

$$\Psi_c(2^3S) = \phi_-(r_1, r_2)\begin{cases} \alpha(1)\alpha(2) & M_s = 1 \\ \frac{1}{\sqrt{2}}(\alpha(1)\beta(2) + \beta(1)\alpha(2)) & M_s = 0 \\ \beta(1)\beta(2) & M_s = -1 \end{cases}$$

write $\phi_-(r_1, r_2) = \frac{1}{\sqrt{2}}(u_{1s}(r_1)u_{2s}(r_2) + u_{2s}(r_1)u_{1s}(r_2))$. Write the three functions of in form of the Slater determinants. (6 marks)

(b) Obtain a pair of Hartree-Fock coupled equations for the spatial orbital's $u_{1s}(r_1)$ and $u_{2s}(r_2)$ corresponding to the 2^3S (M=1) wave function of helium. Prove that the orbital's $u_{1s}(r_1)$ and $u_{2s}(r_2)$ are orthogonal. (8 marks)

QUESTION FOUR (14 MARKS)

(a) (i) Particles A hits particles B (at rest), producing particles C_1, C_2, ...C_n. Show that in the low energy approximation the threshold energy for this reaction in terms of various particles masses is

$$K_{th} = -\frac{Q}{m_2}(m_1 + m_2)$$

where Q is the Q value and m_1 and m_2 are masses of particles A and B respectively. (7 marks)

(ii) Calculate the threshold energy for the following reaction

$$p + p \rightarrow p + p + \pi^0$$

assuming that the target proton is stationary. (3 marks)

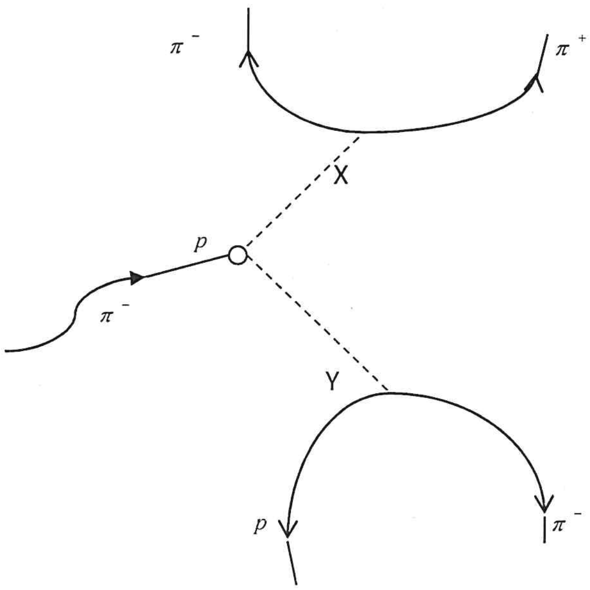
QUESTION FIVE (14 MARKS)

(a) Show that the imaginary part of the complex potential V=-(U+iV) in the optical mode has the effect of absorbing flux from the incident channel. (8 marks)

(b) Nuclear mass of ^{50}Fe iron isotope ^{49}Fe and ^{51}Fe are both known short lived radioactive positron emitters, but ^{50}Fe has not yet been discovered. Using the Weizsacker formula for the liquid drop model of the Nucleus, calculate the value of the expected uclear mass of ^{50}Fe. (6 marks)

QUESTION SIX (14 MARKS)

(a) Figure 1 show a bubble chamber track with the magnetic field directed into the paper. Identify the unknown neutral particles X and Y (dashed tracks). (9 marks)



(b) Before 1964, there are 10 baryons with spin $3/2$. Their symbols and quantum number for charge q and strangeness S are as follows

Baryon	q	S	Baryon	q	S
Δ^-	-1	0	Σ^{*0}	0	-1
Δ^0	0	0	Σ^{*+}	+1	-1
Δ^+	+1	0	Ξ^{*-}	-1	-2
Δ^{++}	+2	0	Ξ^{*0}	0	-2
Σ^{*-}	-1	-1			

Make a charge-strangeness plot for these baryons using the sloping coordinate system. Discuss the features of the resulting symmetry pattern? (5 marks)

QUESTION SIX (14 MARKS)

(c) Show that the imaginary part of the complex potential V=-(U+iV) in the optical mode has the effect of absorbing flux from the incident channel. (8 marks)

(d) Nuclear mass of ^{50}Fe iron isotope ^{49}Fe and ^{51}Fe are both known short lived radioactive positron emitters, but ^{50}Fe has not yet been discovered. Using the Weizsacker formula for the liquid drop model of the Nucleus, calculate the value of the expected uclear mass of ^{50}Fe. (6 marks)