UNIVERSITY EXAMINATIONS
2022/2023 ACADEMIC YEAR

FIRST YEAR SECOND SEMESTER
MAIN EXAMINATIONS

FOR THE DEGREE OF MASTERS IN SCIENCE (PHYSICS)

COURSE CODE: SPH 817

COURSE TITLE: NUCLEAR AND PARTICLE PHYSICS

DATE: 26/04/2023 **TIME:** 9:00-11:00AM

INSTRUCTIONS TO CANDIDATES

TIME: 2 HOURS

Answer any THREE questions

QUESTION ONE [30 MARKS]

a) Differentiate between the following terms-: [4 marks]

(i) Nuclear fusion and nuclear fission

(ii) Pick up and stripping off nuclear reaction processes.

b) Using the semi empirical mass formula of the liquid drop nuclear model, show that the most stable isobar for a given odd A is given by:- $Z = \frac{A}{2+0.0015A^{2/3}}$ [3 marks]

$[b_3 = 0.58MeV, b_4 = 19.3MeV]$

c) Calculate the nuclear binding energy of $(^{238}_{92}U)$. [3 marks]

$[m_p = 1.007825, m_n = 1.008665u$ of mass of $^{238}_{92}U = 238.05076u]$

d) A beam of protons moves through a material whose refractive index is 1.8. Cerenkov light is emitted at an angle of 11^0 to the beam. Find the kinetic energy of the protons in MHz. [3 marks]

e) Find the probability that the neutron- proton separation in deuteron exceeds $2fm$ in the range $0 \leq r \leq \infty$. Use the trial wave function $\psi = \sqrt{2k}exp(-kr)$ [3 marks]

$[k = 0.232fm]$

f) In Fermi gas nuclear model, using the thermodynamic relation $P = -\frac{\partial U}{\partial V}$ show that the pressure inside the nucleus is given by $\frac{2}{5}\rho_n E_F$ where ρ_n is the neutron density. [3 marks]

h) The neutron separation energy of ^4_2He is $1.77MeV$, find its nuclear binding energy. [3 marks]

i) Calculate the magnetic field of a cyclotron which will accelerate protons at a radio frequency of $8MHz$ $[q = 1.6x10^{-19}C, m_p = 1.66x10^{-27}kg]$ [2 marks]

j) A nuclear fission process is given by:- $^{235}_{92}U + ^1_0n \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3^1_0n + Q$. Calculate the energy Q released during the process. [3 marks]

[mass of $^{235}_{92}U$=235.04278u, $m_n = 1.008665u$, mass of $^{141}_{56}Ba$=1409192u and mass of $^{92}_{36}Kr$=91.81719u]

k) Consider elastic scattering of $50MeV$ neutrons from a nucleus. The phase shifts measured in an experiment are $\delta_0 = 96^0$, $\delta_1 = 72^0$, $\delta_2 = 60^0$, $\delta_3 = 35^0$, $\delta_4 = 18^0$ and $\delta_5 = 5^0$ where $\delta_l = 0$ for $l \geq 6$. Find the total cross section [3 marks]

l) Indicate with an explanation whether the following interactions proceed through strong, electromagnetic or weak interactions. [2 marks]

i) $\pi^- \rightarrow \mu^- + \bar{\nu}_p$

ii) $\Sigma^0 \rightarrow \Lambda + \gamma$

iii) $\pi^- + p \rightarrow K^0 + \Sigma^0$

iv) $e^+ + e^- \rightarrow \mu^+ + \mu^-$

QUESTION TWO [15 MARKS]

Explain in detail any two nuclear models [15 marks]

QUESTION THREE [15 MARKS]

Discuss the properties of the nucleus under the subheadings:- [

(i) Its size, mass, volume and density. [4 marks]

(ii) Its composition [3 marks]

(iii) Its binding energy [3 marks]

(iv) Nuclear forces [5 marks]

QUESTION FOUR [15 MARKS]

In detail discuss and classify elementary particles [15 marks]

QUESTION FIVE [15 MARKS]

a) For protons in nucleus, if the charge is uniformly spherically distributed. Obtain an expression for the Coulomb electrostatic energy of the nucleus. [9 marks]

b) Calculate the radius and Coulomb energy of $(^{73}_{32}Ge)$ $[r_0 = 1.4fm]$ [6 marks]