KIBABII UNIVERSITY

UNIVERSITY EXAMINATIONS
2021/2022 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: 11/05/2022 **TIME:** 9:00AM-11:00AM

INSTRUCTIONS TO CANDIDATES

TIME: 2 HOURS

Answer any THREE questions

QUESTION ONE [30 MARKS]

a) Define the following terms-: [2 marks]

(i) Mass defect

(ii) Binding fraction

(iii) Separation energy

(iv) Incident flux

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 (^3_2He). Find its neutron separation energy. [3 marks]

$[m_p = 1.007825, m_n = 1.008665u$ of mass of $^3_2He = 3.01603u]$

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) Show that the expectation value of potential energy of a proton – neutron system described by a square well of depth V_0 and width $0 \leq r \leq R$ is given by $\langle V \rangle = -V_0A^2\left[\frac{R}{2} - \frac{sin2kR}{4k}\right]$ using the trial wave function $\psi = Asinkr$. [4 marks]

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]

g) Identify particle X detected in the following nuclear reaction equation [1 marks]

$^{150}_{62}Sm + ^1_1H \rightarrow X + ^{147}_{61}Pm$

h) Find the ground state angular momentum of $^{20}_{10}Ne$. [2 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) In nuclear scattering, calculate the angle of scattering in laboratory frame of reference due to two photons if the angle of scattering in centre of mass frame of reference is 10^0. [2 marks]

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

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

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) The electric quadrupole moment of nuclear charge distribution which is symmetric about z-axis is given by:- [8 marks]
$\mu = \frac{1}{e}\int(3z^2 - r^2)\rho(x,y,z)dxdydz$ for a uniformly charged ellipsoid of revolution defined by the equation:- $\frac{x^2+y^2}{a^2} + \frac{z^2}{b^2} = 1$. Show that the electric quadrupole moment is given by:- $\mu = \frac{6z}{5}R_0^2\left(\frac{\delta R_0}{R_0}\right)$.

b) Show that the Coulomb energy is given by:- $E_C = \frac{3}{5}\frac{kZ(Z-1)e^2}{R}$ for a proton in nucleus if the charge is uniformly spherically distributed. [7 marks]