(*University of Choice*)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

UNIVERSITY EXAMINATIONS
2021/2022 ACADEMIC YEAR

FOURTH YEAR SECOND SEMESTER MAIN EXAMINATIONS

FOR THE DEGREE
OF
BACHELOR OF SCIENCE IN PHYSICS

COURSE CODE: SPH 411

COURSE TITLE: NUCLEAR PHYSICS

DATE: WEDNESDAY 27TH APRIL, 2022   **TIME**: 12:00 PM – 2:00 PM

INSTRUCTIONS TO CANDIDATES
TIME: 2 Hours

Answer question ONE and any TWO of the remaining.
Symbols used bear the usual meaning.
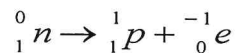
MMUST observes ZERO tolerance to examination cheating

QUESTION ONE (30 MARKS)

a) Explain the term K-capture as used in radio-active decay (1 mark)

b) Show that the nuclear density is a constant and is given by $\rho = \dfrac{1}{\frac{4}{3}\pi R_0^3}$. Hence determine its value given that $R_0 = 1.12$ fm and 1 fm $= 10^{-15}$m . (3 marks)

c) The polonium isotope $^{210}_{84}Po$ is unstable and emits a 5.30-MeV alpha particle. The atomic mass of $^{210}_{84}Po$ is 209.9829 u and that of $^{4}_{2}He$ is 4.0026au. Identify the daughter nuclide and find its atomic mass (3 marks)

d) Discuss the origin of Yukawa's meson indicating its diagram. (3 marks)

e) Discuss the major families of matter as described in elementary particles. (3 marks)

f) Define the term particle accelerator and explain the two types of accelerators. (3 marks)

g) Show that for a beam of particles incident on a thin sheet of material of n nuclei per unit volume, thickness x, area A, the number of surviving particles which decreases exponentially with the slab thickness is given by;
$$N = N_0 e^{-n\sigma x}$$
(3 marks)

h) The Heisenberg's uncertainty principle is given as $\Delta x\, \Delta p \geq \dfrac{h}{2\pi}$. Given $\Delta x = 10^{-15}$m, m_e =9.1 $\times$ 10^{-31}kg, h = 6.63 x 10^{-34}Js and $\pi = 3.1415$, determine the velocity of a beta particle in the nucleus and explain what this velocity means. (2 marks)

i) Give the two main classifications of nuclear detectors giving two examples for each. (2 marks)

j) Calculate the energy released during the following fusion reaction
$$^{0}_{1}n \rightarrow\, ^{1}_{1}p +\, ^{-1}_{0}e$$
Where mass of $^{1}_{1}p$= 1.0072 a.m.u.; mass of $^{1}_{0}n$ = 1.0086 a.m.u. and mass of $^{-1}_{0}e$ = 0.00055 a.m.u. (3marks)

k) The four factor formula of nuclear fission which gives the *effective neutron multiplication factor* is given by $k_{eff} = \eta f p \varrho$. Explain the four factors given in the formula. (4 marks)

QUESTION TWO (20 MARKS)

a) Discuss the Shell model of the nucleus, giving an account of the Aufbau principle of nuclear shell filing, outlining the prediction of nuclear spin and parity. (10 marks)

b) The Bethe-Weizacker Semi-empirical Mass Formula for the liquid drop model accounts for the total nuclear binding energy. Write the formula and explain the five factors contributing to the formula. (10 marks)

QUESTION THREE (20 marks)

a) Discuss the Ionisation Chamber nuclear detector outlining its construction and the working principle. (10 marks)

b) Outline the efficiency of nuclear detectors, discussing the characteristics of a perfect detector. (10 marks)

QUESTION FOUR (20 marks)

a) Discuss the nuclear Fission process showing a clear diagram of how a neutron interacts with a target producing fission products   (8 marks)

b) Deduce the Geiger-Nuttall law of alpha decay. Hence state how it relates with the decay constant.   (12 marks)

QUESTION FIVE (20 marks)

a) Discuss the compound nuclear theory, describing the major conservation laws.

                                        (8 marks)

b) Discuss the Cyclotron accelerator giving its working principle, construction, theory, utility and working principle.   (8 marks)

c) Give the two major types of nuclear accelerators, explaining each of them.   (4 marks)