THE CATHOLIC UNIVERSITY OF EASTERN AFRICA

A. M. E. C. E. A

MAIN EXAMINATION

JANUARY – APRIL 2022

FACULTY OF SCIENCE

DEPARTMENT OF NATURAL SCIENCES

REGULAR PROGRAMME

PHY 306: INTRODUCTORY NUCLEAR PHYSICS

Date: APRIL 2022	Duration: 2 Hours
INSTRUCTIONS: Answer Question ONE and any TWO Questions	

Physical Constants

Mass of proton, m_p = 1.007276 u

Mass of neutron m_n = 1.008665 u

Mass of electron m_e = 0.00055 u

1 amu = 931.5 MeV

Up-type quark, $u = +\frac{2}{3} e\, u = +\frac{2}{3} e$

Down-type quark, $d = -\frac{1}{3} e - \frac{1}{3} e$

Speed of light, $c = 3 \times 10^8$ m/s

Avogadro's number, $N_A = 6.023 \times 10^{23}$ atoms/mol

Q1.

a) Calculate the rest energy (in MeV) for a material of 2.5g **(3 marks)**

b) Calculate the Binding energy per nucleon for Pb (A = 208, Z= 82) of mass M_A =

207.976637u **(3 marks)**

c) Given the following nuclei, $^{12}_{6}C, ^{13}_{7}N, ^{14}_{6}C, ^{19}_{9}F, ^{13}_{6}C, ^{14}_{7}N, ^{19*}_{9}F,$ $^{12}_{6}C, ^{13}_{7}N, ^{14}_{6}C, ^{19}_{9}F, ^{13}_{6}C, ^{14}_{7}N, ^{19*}_{9}F,$ identify a pair of

    i) Isotopes **(2 marks)**

    ii) Isotones **(2 marks)**

    iii) Isobars **(2 marks)**

    iv) Isomers **(2 marks)**

d) A certain source gives 2000 counts per second (cps) at t = 0. Given that its

half-life is 2 min, determine the count rate after 8 min **(3 marks)**

e) Identify the composition of nucleons and hence verify their charges **(4 marks)**

f) Determine the energy needed to remove a neutron from $^4_2He^4_2He$ given that mass

of $^4_2He = 4.002603\ u; of\ X = 3.016029\ u;$

$^4_2He = 4.002603\ u; of\ X = 3.016029\ u;$ **(3 marks)**

g) Estimate the density of a nuclear material when the mass of one nucleon in the

nucleus is one atomic mass unit **(3 marks)**

h) The nucleus of $^{60}_{27}Co$ irradiates a photon with energy of 2.15 x 10-13 J. Calculate

the mass defect in this isotope **(3 marks)**

Q2. Briefly describe the fundamental forces in nature with respect to strength, carrier
particles, range and application (Use a table) **(20 marks)**

ISO 9001:2015 Certified by the Kenya Bureau of Standards

Q3.

a) In a fission process, a Pu (A = 239) nucleus splits into two nuclei whose mass number ratio is 3 to 1. Determine the radius of the nuclei formed in this process. **(12 marks)**

b) Write down the decay equations for the following radioactive isotopes

    i) Radium (Ra) – 226 (alpha decay) **(2 marks)**

    ii) Beryllium (Be) – 7 (electron capture) **(2 marks)**

    iii) Carbon(C) -14 (beta minus decay) **(2 marks)**

    v) Aluminium (Al)– 26 (beta plus decay) **(2 marks)**

Q4.

a) Discuss the various components of a typical controlled thermal fission reactor

    (10marks)

b) Show that the activity of 1gram of radium-226 (half- life = 1590 years) is equivalent to a Currie **(10marks)**

Q5.

a) Briefly describe uranium dating method and hence derive an expression used to determine the age of an object **(5 marks)**

b) Wood from a burnt ship has a specific activity of 1.2×10^2 Bqkg^{-1} due to

carbon-14 whereas comparable living wood has an activity of 2.0×10^2 Bqkg^{-1}. Determine the age of the ship given that the half-life of carbon-14 is 5×10^3 years

(7 marks)

c) A nuclear technician exposed to fast neutrons receives a radiation dose of 200 Rem of his hand affecting 25g of tissue. The RBE of fast neutrons is 10. How many rad and joules of energy did he receive? **(8 marks)**

END