UGANDA MARTYRS UNIVERSITY

FACULTY OF SCIENCE

DEPARTMENT OF NATURAL SCIENCE

SEMESTER TWO EXAMINATIONS – 2022 / 2023

PAPER CODE	: PHY 3204
PAPER NAME	: NUCLEAR AND PARTICLE PHYSICS
DURATION	: 3 Hours
YEAR OF STUDY	: THREE
DATE OF EXAM	: MAY , 2023
TIME OF EXAM	: 2:00-5:00PM

INSTRUCTION (S) :

- ◊ Answer any ***FIVE*** questions.
- ◊ Begin each question you are answering on a fresh page.
- ◊ Read the additional instructions provided on the answer booklet.

Where necessary assume the following universal constants:

Planck's constant	$h = 6.63 \times 10^{-34}\ J\,s$
Boltzmann's constant	$K_B = 1.38 \times 10^{-23} JK^{-1}$
Mass of electron	$m_e = 9.11 \times 10^{-31}\ kg$
Electronic charge	$e = 1.60 \times 10^{-19}\ C$
Speed of light	$c = 3.0 \times 10^{8}\ ms^{-1}$
Avogadro's number	$NA = 6.02 \times 10^{23}\ mol^{-1}$
Universal gas constant	$R = 8.31\ JK^{-1}mol^{-1}$
Acceleration due to gravity	$g = 9.81 ms^{-2}$
1 standard atmosphere	$= 1{:}01 \times 10^{5} Nm^{-2}$
Radius of Earth	$R_e = 6.38 \times 10^{6}\ m$
Solar constant	$S = 1.37 \times 10^{3}\ Js^{-1}m^{-2}$
Universal constant	$G = 6.67 \times 10^{-11} Nm^2kg^{-2}$
Coulomb constant	$K = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^{9}$

QUESTION ONE

a. Define the following terms:
   i. Cross section. **(1 marks)**
   ii. Absorption cross section. **(2 marks)**
   iii. Macroscopic cross section. **(2 marks)**

b. A beam of 1-MeV neutrons of intensity 5×10^8 neutrons/cm^2-sec strikes a thin 12 C target. The area of the target is 0.5cm^2 and it is 0.05 cm thick. The beam has a cross sectional area of 0.1cm^2. At 1-MeV, the total cross section of 12 C is 2.6 b.
   i. At what rate do interactions take place in the target? **(5 marks)**
   ii. What is the probability that a neutron in the beam will have a collision in the target? **(4 marks)**

c. A 1-MeV neutron is scattered through an angle of 45^0 in a collision with a ^{2}H nucleus.
   i. What is the energy of the scattered neutron? **(2 marks)**
   ii. What is the energy of the recoiling nucleus? **(2 marks)**
   iii. How much of a change in lethargy does the neutron undergo in this collision? **(2 marks)**

QUESTION TWO

a. List and briefly explain the frames of references considered for neutron moderation. **(5 marks)**

b. Derive the fractional energy $\frac{E_1}{E_0} = \frac{[1+A^2+2A\cos\theta]}{[1+A]^2}$ **(4 marks)**

c. Define the following terms as related to neutron physics:
   i. Slowing Down Power. **(2 marks)**
   ii. Average Log Energy Decrement. **(2 marks)**
   iii. Cross section in moderating process. **(2 marks)**
   iv. Resonance effect. **(2 marks)**

d. In an experiment to measure the total cross-section of lead for 10 MeV neutrons, it is found that 1 cm thick lead attenuate neutron flux to 84.3 percent of its initial value. The atomic weight of lead is 207.21 and its specific gravity is 11.3.Calculate the total cross-section. **(3 marks)**

QUESTION THREE

a. i. State the diffusion equation and explain what each term of the equation stands for. **(4 marks)**

ii. What are the conditions imposed on the diffusion equation to get the neutron flux? **(3 marks)**

iii. Describe the Physics of the diffusion length with respect to the average of the square of the distance that a neutron travels. **(4 marks)**

b. i. State three conditions under which the Fick's law is not valid. **(3 marks)**

ii. Deduce the diffusion length and diffusion area from the diffusion equation. **(3 marks)**

c. It has been shown in this unit that the flux at the distance r from a point source emitting S neutrons per second in an infinite moderator is given by the formula,

$$\emptyset(r) = \frac{Se^{-r/L}}{4\pi Dr}$$

Where L is a constant? Find expression for,

i. The neutron current in the medium, **(1 mark)**

ii. The net number of neutrons flowing out through a sphere of radius r surrounding the source. **(2 marks)**

QUESTION FOUR

a. i. Distinguish between nuclear fission and nuclear fusion. **(3 marks)**

ii. Describe the conditions necessary for nuclear fusion to take place. **(4 marks)**

iii. Mention one example each of physical phenomenon where nuclear fission and fusion can take place. **(3 marks)**

b. i. Define the utilization factor in a nuclear reactor. **(2 marks)**

ii. What do you understand by the criticality of a reactor? **(2 marks)**

iii. Derive the buckling factor from the diffusion equation. **(3 marks)**

iv. Briefly explain how K_∞ can be controlled in a nuclear reactor. **(3 marks)**

QUESTION FIVE

a. Briefly explain the process involved in a nuclear fission reaction. **(4 marks)**

b. i. What do you understand by the term neutron yield? **(2 marks)**

ii. Explain the process involved in making a hydrogen bomb. **(4 marks)**

iii. Briefly explain the different critical state of a nuclear reactor. **(5 marks)**

c. Name the classes of nuclear reactors. **(5 marks)**

QUESTION SIX

a. Explain briefly what happens to the reaction cross- section of neutron when their energies are lowered. **(7 marks)**

b. i. Explain briefly how to moderate generated neutrons from nuclear fission reaction in a reactor. **(4 marks)**

ii. Give two properties of a moderator. **(2 marks)**

iii. List the problems of thermal reactors. **(7 marks)**

END