MAASAI MARA UNIVERSITY

REGULAR UNIVERSITY EXAMINATIONS
2023/2024 ACADEMIC YEAR
FIRST YEAR SECOND SEMESTER

SCHOOL OF PURE APPLIED AND HEALTH SCIENCES

DEGREE OF BACHELOR OF EDUCATION (SCIENCE) AND BACHELOR OF SCIENCE

COURSE CODE: PHY 1207-1

COURSE TITLE: MODERN PHYSICS

DATE: 15/5/2024 **TIME: 1100-1300 HRS**

INSTRUCTIONS

- Answer Question ONE and any other TWO.
- Use of sketch diagrams where necessary and brief illustrations are encouraged.
- Read the instructions on the answer booklet keenly and adhere to them.

PHYSICAL CONSTANTS

- Planck constant ; $h = 6.626 \times 10^{-34} Js$
- Charge of proton; $e = +1.602 \times 10^{-19} C$
- Mass of electron; $m_e = 9.109 \times 10^{-31} kg$
- Acceleration due to gravity, $g = 9.81\ m\ s^{-2}$
- Avogadro constant; $N_A = 6.023 \times 10^{23} mol^{-1}$
- Stefan constant ; $\sigma = 5.670 \times 10^{-8} Wm^{-2}K^{-4}$
- Rydberg constant; $R_{hc} = 1.097 \times 10^{7} m^{-1}$
- Speed of light in vacuum; $c = 2.998 \times 10^{8} ms^{-1}$
- Charge of electron; $e = -1.602 \times 10^{-19} C$
- Mass of proton; $m_p = 1.67 \times 10^{-27} kg$
- Rest energy of electron; $E_e = 0.511 MeV$
- One atomic mass unit; $u = 1.66 \times 10^{-27} kg$
- Atomic mass unit energy equivalent ; a.m.u = 931.5MeV
- One ElectronVolt ; $1eV = 1.602 \times 10^{-19} J$

QUESTION ONE: [20 marks]

a) Electrons are emitted from the surface in photoelectric effect is almost instantaneously, even at low intensities. Explain. [2]

b) State the second postulate of Special relativity theory as postulated by Einstein in 1905. [2]

c) State Wein's law of black body radiation. [3]

d) Photons of light have zero mass but possess momentum. Explain. [2]

e) The Balmer series for the hydrogen atom corresponds to electronic transitions that terminate in the state of quantum number n = 2.

(i) Find the longest-wavelength photon emitted and determine its energy [4]

(ii) Find the shortest-wavelength photon emitted in the Balmer series. [3]

f) State the physical meaning of the square of the wave function as postulated by Born [2]

g) Determine energy of the photons in a 1240 nm infrared light beam in eV. [2]

QUESTION TWO: [15 marks]

a) State the de Broglie postulate [2]

b) X-rays of wavelength λ= 0.200 nm are aimed at a block of carbon. The scattered x-rays are observed at an angle of 45.0^o to the incident beam. Calculate the increased wavelength of the scattered x-rays at this angle. [5]

c) Why are x-ray photons used in the Compton experiment, rather than visible-light photons? To answer this question, we shall first calculate the Compton shift for scattering at 90^o from graphite for the following cases:

(i) Very high energy γ-rays from cobalt, λ = 0.0106 Å;

(ii) x-rays from molybdenum, λ = 0.712 Å; and

(iii) green light from a mercury lamp, λ = 5461 Å. [5]

d) The so-called free electrons in carbon are actually electrons with a binding energy of about 4 eV. Why may this binding energy be ignored for x-rays with λ_o= 0.712 Å? [3]

QUESTION THREE: [20 marks]

a) State the THREE postulates of Bohr. [3]

b) From the concept of conservation of energy and quantization of angular momentum in the Bohr's model of a Hydrogen atom, show that $E = \frac{mk^2e^4}{2n^2\hbar^2}$ and calculate the Bohr radius and the corresponding energy of the first excited state for hydrogen. [12]

QUESTION FOUR: [15 marks]

a. Briefly explain the Planck's law of black body radiation [2]
b. State two applications of the study of black body. [2]
c. Discuss the Rayleigh-Jeans Law of black body radiation. [5]
d. Explain the Ultraviolet catastrophe [6]

QUESTION FIVE: [15 marks]

a) Explain the term 'nuclear fission' [2]

b) Define the term atomic mass unit (u), and show that 1amu $= 1.49 \times 10^{-10}$ J. [3]

c) Calculate the binding energy (in MeV) of an alpha particle from the following information: (ans. to 1 d.p.). Take Mass of a proton = 1.0076 u ; Mass of a neutron = 1.0090 u ; Mass of an alpha particle = 4.0028 u [5]

d) Consider the nuclear fusion below and determine the energy released per fusion.[5]

$${}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n + Energy.$$

Element	Atomic Mass (kg)
${}^{2}_{1}H$	3.345×10^{-27}
${}^{3}_{1}H$	5.008×10^{-27}
${}^{4}_{2}He$	6.647×10^{-27}
${}^{1}_{0}n$	1.6750×10^{-27}

Calculate the following: (i) The mass difference (ii) The energy released per fusion.

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