MAASAI MARA UNIVERSITY

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

SCHOOL OF PURE, APPLIED AND HEALTHY SCIENCES
BACHELOR OF SCIENCE(PHYSICS) AND BACHELOR OF EDUCATION (SCIENCE)

COURSE CODE: PHY 3221-1
COURSE TITLE: Quantum Mechanics

DATE: 28/5/24 **TIME: 8.30AM – 10.30AM**

INSTRUCTIONS TO CANDIDATES

- **Question One is Compulsory**
- **Answer Any Other Two Questions**
  - **You may use the following Constants**
  - **h = 6.64 x 10 -34 Js, c= 3 x 10 8 m/s, RH= 1.097 X 107 m-1**
  - **m_e = 9.11 X 10-31 kg,e = 1.60 X 10-19 C, m_p = 1.67 X 10-27 kg**

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QUESTION ONE(20 Marks)

a. State three properties of Matter waves (**3marks**)

b. What is Quantum Mechanics? (**1marks**)

c. Give three characteristics of a well behaved wave function Ψ(x) **(3marks)**

d. Given the wave function Ψ(x) is given by $\psi = e^{i(kx-\omega t)}$ show that $E = \frac{p^2}{2m}$ using the energy operator. Where E is the energy, p is the momentum , m is the mass of the electron, ω is the angular frequency (**3marks)**

g. Verify that momentum Operator p acting on the wave function Ψ(x, t) for a particle of momentum p it gives p times the wave function Ψ(x, t) , given as **(3marks)**

$$\hat{p}\,\psi = p\psi$$

i. Explain how Compton effect disagrees with photoelectric effect. **(2 marks)**

j. Calculate the de Broglie wavelength for an electron (m_e = 9.11 X 10^{-31} kg) moving at 1.00 x 10^7 m/s. (**2 marks**)

k. (i) State the Heisenberg uncertainty principle **(1 marks)**

(ii)The speed of an electron is measured to be 5.00 X 10^3 m/s to an accuracy of 0.003 00%. Find the minimum uncertainty in determining the position of this electron. (**2marks**)

QUESTION TWO [15 marks]

In quantum mechanics, the total energy, the kinetic energy, and the momentum are expressed in terms of differential operators. The wave function is described by the function $\psi = e^{i(kx-\omega t)}$. Given that p=ħk and E=ħω ,

i. show that $E = i\hbar\frac{d}{dt}$, [**3marks**]

ii. $K.E = -\frac{\hbar^2}{2m}\frac{d^2}{dx^2}$ and [**3marks**]

iii. $p = -i\hbar\frac{d}{dx}$ [**4marks**]

iv. Derive the Schrodinger equation using equation (i) results. [**5marks**]

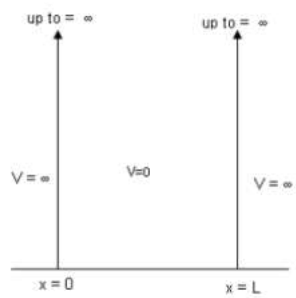
QUESTION THREE [15 Marks]

A particle moving freely in one-dimensional “box” of length ‘L’ trapped completely within the box is imagined to be as a particle in a potential well of infinite depth. As shown in the figure below

Initial conditions

$V(x) = 0 \; ; \; 0 < x < L$

$V(x) = \infty \; ; \; x < 0, \; x > L$



Determine an expression for the energy Eigen values for a particle trapped in this potential well of infinite depth.

QUESTION FOUR [15 marks]

a. Using the basis vectors of S_z, eigenvectors, calculate

i. Si|+l/2> and [**5marks**]

ii. Si|-1/2> (i = X, y, z). where |+1/2> and |-1/2> are the eigenvectors of S_z, with eigenvalues +h/2 and -h/2, respectively. [**5marks**]

b. Determine the commutator of the following operators [x, p] **[5marks]**

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