MAASAI MARA UNIVERSITY

UNIVERSITY EXAMINATIONS

2018/2019 ACADEMIC YEAR

THIRD YEAR SECOND SEMESTER UNIVERSITY EXAMINATIONS FOR THE DEGREE OF BACHELOR OF SCIENCE (PHYSICS) AND BACHELOR OF EDUCATION (SCIENCE)

COURSE CODE: PHY 3221
COURSE TITLE: QUANTUM MECHANICS I

DATE: 29TH APRIL 2019 **TIME: 11.00AM -1.00 PM**

INSTRUCTIONS:

- **Answer Question ONE (30 MARKS) and any other TWO (20 MARKS EACH).**
- **Read the instructions on the answer booklet keenly and adhere to them.**

You may use the following

$h = 6.6 \times 10^{-34}$ Js, $c = 3 \times 10^{8}$ m/s, $R_H = 1.097 \times 10^{7}\ m^{-1}$

$Me = 19.11 \times 10^{-31}$ kg

$e = 1.60 \times 10^{-19}$ C

$Mp = 1.67 \times 10^{-27}$ kg

QUESTION ONE

1. a. Briefly explain the following as used in Quantum Mechanics (3mks)
    - (i) Wave Function
    - (ii) Operator
    - (iii) Eigen functions

b. An electron in a hydrogen atom jumps from the n=5 to n=3 level.

- **i.** Is a photon absorbed or emitted in this process? (2 marks)
- **ii.** Calculate the energy of the photon and its wavelength. State whether it is in the visible range or not. (2 marks)

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

d. Explain the inadequacy of classical theory in explaining photoelectric effect (3 marks)

e. X-rays of wavelength $\lambda = 0.200\ 000$ nm are scattered from a block of material. The scattered x-rays are observed at an angle of 45.0° to the incident beam. Calculate their wavelength. (3 marks)

f. Given that $\Theta = \frac{d^2}{dx^2}$ and $\Psi(x) == Ae^{-ikx}$ find the eigen value ,ε (3 mks)

g. Define the term 'blackbody' (1mrk)

h. Explain how the wave picture of light failed to explain the behavior of blackbody radiations (2 marks)

i. Explain how Compton effect disagrees with photoelectric effect. (3mks)

j. Calculate the de Broglie wavelength for an electron (me = 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 5.00X 10^3 m/s to an accuracy of 0.003 00%. Find the minimum uncertainty in determining the position of this electron. (2 marks)

QUESTION TWO

a. 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 $(x) = Ae^{i(kx-\omega t)}$. Show that $E = i\hbar\frac{d}{dt}$, $K.E = -\frac{\hbar^2}{2m}\frac{d^2}{dx^2}$ and $p = -i\hbar\frac{d}{dx}$ hence derive the Schr$\ddot{o}$dinger equation (8 marks)

b. If ,Θ_1 and Θ_2 are two operators ,prove that $(\Theta_I\,\Theta_2)^+ = \Theta_1^+\,\Theta_2^+$ (5mks)

c. Define a Hermitian operator and hence show that the momentum operator is Hermitian. (5 marks)

d. Differentiate between a unitary and an identity operator (2 marks)

QUESTION THREE

a. State Bohr's postulates concerning the model of the atom (4 marks)

b. Show that the energy of an electron in an allowed orbit is given by E = - $\frac{13.6}{n^2}$ eV hence calculate the wavelength of a photon emitted as a result of the n=4 to n=3 transition. (8 marks)

c. Calculate the probability that the electron in the ground state of hydrogen will be found outside the first Bohr radius. (4 marks)

d. For a hydrogen atom, determine the allowed states corresponding to the principal quantum number n = 3 and calculate the energies of these states. (4 marks)

QUESTION FOUR

a. A particle of mass m is confined and moves along the X-axis in an interval $-\frac{a}{2} < x < \frac{a}{2}$ by the potential energy

$$U_x = \begin{cases} \infty \quad for\ x < a/2 \leq \\ 0 \quad for\ -\frac{a}{2} < x < \frac{a}{2} \\ \infty \quad for\ x > a/2 \end{cases}$$

Find the solution to the Schrödinger equation by utilizing the boundary conditions and for n=even (10 Marks)

b. The average value of an operator is given by $\langle \theta \rangle = \langle \Psi I \theta I \Psi \rangle$ while the expectation value is given by $\Delta\theta = \sqrt{\langle \theta^2 \rangle - \langle \theta \rangle^2}$ show that

$$(i)\ \langle x \rangle = 0$$

$$(ii)\ \langle P \rangle = 0$$

(iii) And for n=1 $\Delta x \Delta P = 0.568\hbar$ (10 Marks)

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