THE CATHOLIC UNIVERSITY OF EASTERN AFRICA

A. M. E. C. E. A

P.O. Box 62157
00200 Nairobi - KENYA
Telephone: 891601-6
Fax: 254-20-891084
E-mail:academics@cuea.edu

MAIN EXAMINATION

JANUARY – APRIL 2015 TRIMESTER

FACULTY OF SCIENCE

DEPARTMENT OF NATURAL SCIENCES (PHYSICS)

SCHOOL FOCUSED PROGRAM

PHY 301: QUATUM MECHANICS I

Date: April 2015	**Duration: 2 Hours**
Instructions: Answer Question ONE and any other TWO Questions	

Note: Important Physical Constants and Formulae

R - Reydberg Constant = $1.097 \times 10^{7} m^{-1}$
h - Plank Constant in eV = $4.136 \times 10^{-15} eV.s$
c - Speed of light = $3.0 \times 10^{8} m/s$
e - electronic charge = $1.6 \times 10^{-19} c$

$$\hbar = \frac{h}{2\pi}$$

Q1 a) i) State Heisenberg uncertainty principle **(1 marks)**

ii) State Pauli exclusion principle **(1 marks)**

iii) State four deficiencies of the Bohr atomic model. **(4 marks)**

b) Distinguish between the Compton effect and the photoelectric effect. **(3 marks)**

c) What assumptions were made by Plank in dealing with the problem of blackbody radiation? **(2 marks)**

d) Given four possible transitions for a hydrogen atom;
(A) $n_i = 2$; $n_f = 5$
(B) $n_i = 5$; $n_f = 3$
(C) $n_i = 7$; $n_f = 4$ and

(D) $n_i = 4$; $n_f = 7$

For which transition (s) does the atom lose energy? Explain.

(4 marks)

e) What will be the kinetic energy of an electron if its de Broglie Wavelength equals the wavelength of the yellow line of Sodium (5896 $\overset{0}{A}$)? The rest mass of electron is $M_0 = 9.1 \times 10^{-31}$Kg, $h = 6.63 \times 10^{-34}$J.S.

(4 marks)

f) Define the following terms as applied in quantum mechanics;

i) Expectation value of a particle **(1 mark)**
ii) Observable **(1 mark)**
iii) Operator **(1 mark)**

g) Briefly explain Thomson's atomic model.

(4 marks)

h) i) State the major significance of Rutherford's atomic model.

(4 marks)

ii) The peak in the radiation from the sun occurs at about 500nm. What is the sun's surface temperature, assuming it radiates as a blackbody. (Use wien's Law).

(3 marks)

Q2. a) State the two ways in which the spectral lines form an atomic species can be observed.

(2 marks)

b) State three postulates of the Bohr's atomic model.

(3 marks)

c) The electron in a hydrogen atom at rest makes a transition from the n=2 energy state to the n = 1 ground state. Find;

i) The wavelength of the emitted photon. **(4 marks)**
ii) The frequency of the emitted photon **(3 marks)**
iii) The energy of the emitted photon **(3 marks)**

d) Suppose that light of total intensity 1.0 $\mu W / cm^2$ falls on a certain iron sample 1.0cm in area. Assume that the iron sample reflects 96% of the light and that only 0.3% of the absorbed energy lies in the violet region of the spectrum above the threshold frequency.

i) What intensity is actually available for the photoelectric effect?

(3 marks)

ii) Assuming that all the photons in the violet region have an effective wavelength of 250nm, how many electrons will be emitted per second?

(2 marks)

Q3. a) A particle of charge q and mass m is accelerated from rest through a small potential difference V.

i) Find its de Broglie wavelength assuming that the particle is non-relativistic.

(5 marks)

ii) Calculate λ if the particle is an electron and V = 50 volts.

(2 marks)

(h=6.63 x 10^{-34}J.S, M_e = 9.11 x 10^{-31}Kg

b) Starting with the expression for the wavefunction ψ for freely moving particle in positive x – direction with total energy E and momentum p as

$$\psi = Ae^{-\left(\frac{i}{\hbar}\right)(Et-px)}$$

Show that the time-dependent one dimensional schrodinger equation is given as

$$(i\hbar\frac{\partial\psi}{\partial t} = \frac{\hbar^2}{2m}\frac{\partial^2\psi}{\partial x^2} + V\psi)$$

(m is mass of the particle and V is potential energy).

(13 marks)

Q4. a) Explain the followign terminologies;

i) Normal Zeeman effect **(1 mark)**

ii) Anomalous Zeeman effect **(1 mark)**

b) State the three properties of the electron spin.

(6 marks)

c) Assuming that the atom is in a magnetic field of strength B=1.00T. Calculate;

i) The magnetic energy for an electron in the n = 2 state of hydrogen in eV.

(4 marks)

ii) The Larmor frequency for an electron in the n = 2 estate of hydrogen.

(3 marks)

d) Explain field emission as an application of tunneling phenomena.

(5 marks)

Q5. a) State the Bohr's correspondence principle and give its symbolic representation.

(1 mark)

b) A block of mass 0.2Kg oscillates at the end of a spring (K = 5N/m) with an amplitude of 10cm.

i) What is its quantum number n?

(5 marks)

ii) Under what conditions does the quantum effect becomes significant?

(1 mark)

c) Show that the allowed energy levels of hydrogen atom are given by $E_n = -\frac{m_e e^4}{32\pi^2 \in_0^2 \hbar^2 n^2}$, where, n = 1, 2, 3, …..

(13 marks)

END