CHUKA UNIVERSITY

UNIVERSITY EXAMINATION

FIRST YEAR EXAMINATION FOR THE AWARD OF DEGREE OF BACHELOR OF SCIENCE (GENERAL) & BACHELOR OF EDUCATION (SCIENCE)

PHYS 134: INTRODUCTION TO QUANTUM PHYSICS

STREAMS: BSc. (GEN), B Ed. (SCIENCE) Y1S2 **TIME: 2 HOURS**

DAY/DATE: FRIDAY 12/04/2019 **11.30 A.M – 1.30 P.M**

INSTRUCTIONS:

- **Attempt question ONE (30 marks) and any other TWO questions (20 marks each).**
- **Start each question on a fresh page**

USEFUL CONSTANTS

Wiens displacement constant b = 2.898 x 10^{-3} m.K
Planck's constant h = 6.63 x 10^{-34} J.s = 4.14 × 10−15 ( ) eV.s
Mass of an electron M_e = 9.1 x 10^{-31} kg
Reduced Planck's constant $\hbar$=¿ 1.055 x 10^{-34} J.S
Electronic charge e = 1.6 x 10^{-19} C

QUESTION ONE (Compulsory: 30 Marks)

a. Using suitable illustrations, explain what a blackbody is in terms of absorption and radiation of heat energy. (4marks)

b. State Wien's displacement law. (1mark)

c. Determine the peak wavelength of the blackbody radiation emitted by the Sun, which has a surface temperature of 5 800 K. (3marks)

d. Explain what the half-life of a radioactive substance is. (2marks)

e. The isotope carbon-14, ${}^{14}_{6}C$, is radioactive and has a half-life of 5 730 years. If you start with a sample of 1 000 carbon-14 nuclei, how many nuclei will still be undecayed in 25000 years? (4 marks)

f. Estimate the energy of the characteristic x-ray emitted from a tungsten target when an electron drops from an M shell (n = 3 state) to a vacancy in the K shell (n = 1 state). The atomic number for tungsten is Z = 74. (5 marks)

g. State and explain Heisenberg's uncertainty principle. (3 marks)

h. The speed of an electron is measured to be 5 x 10^3 m/s to a precision of 0.003%. Find the minimum uncertainty in determining the position of the electron. (5 marks)

i. A ball of mass 50g and a de Broglie wavelength of 3.32 x 10^{-34} m is thrown up. Determine its speed. (3 marks)

QUESTION TWO (Elective: 20 Marks)

a. State and explain Bohr's postulates that were used to predict the spectrum of the hydrogen atom. (3 marks)

b. Show that the energy for the quantized states of a hydrogen atom is given by:- (9 marks)

$$E_n = \frac{-13.606}{n^2} e$$

c. Calculate the wavelength of light for the least energetic photon emitted in the Lyman series of the hydrogen atom spectrum lines. (5 marks)

d. Determine the series limit for the Lyman series. (3 marks)

QUESTION THREE (Elective: 20 Marks)

a. State Planck's assumptions in his explanation of blackbody radiation and explain how this explanation relates with experimental observation. (4 marks)

b. A 2.00-kg block is attached to a massless spring that has a force constant of k= 25.0 N/m. The spring is stretched 0.400 m from its equilibrium position and released from rest. Determine:-

i. the total energy of the system (4marks)

ii. the frequency of oscillation according to classical calculations. (4 marks)

c. Assuming the energy of the oscillator is quantized, find the quantum number n for the system oscillating with this amplitude. (4 marks)

d. Suppose the oscillator makes a transition from the $n = 5.36 \times 10^{33}$ state to the state corresponding to $n = 5.36 \times 10^{33}$, by how much does the energy of the oscillator change in this one-quantum change? (4 marks)

QUESTION FOUR (Elective: 20 Marks)

a. State and explain the factors affecting the photoelectric effect. (4 marks)

b. Two light sources are used in a photoelectric experiment to determine the work function for a particular metal surface. When green light incident on the metal surface from a mercury lamp of wavelength 546 nm is used, a stopping potential of 0.4V reduces the photocurrent to zero.

i. Based on this measurement, what is the work function for this metal? (8 marks)

ii. What stopping potential would be observed when using the yellow light from a helium discharge tube of wavelength 590 nm? (8 marks)

QUESTION FIVE (Elective: 20 Marks)

a. Using a suitable illustration, explain what the Compton effect is. (3 marks)

b. X-rays having energy of 300 keV undergo Compton scattering from a target. The scattered rays are detected at 37° relative to the incident rays. Determine:-

i. The Compton shift at this angle (5 marks)

ii. The energy of the scattered X-rays (6 marks)

iii. The energy of the recoiling electron (6 marks)
