



UNIVERSITY EXAMINATIONS
FIRST YEAR EXAMINATION FOR THE AWARD OF DEGREE OF BACHELOR
OF SCIENCE AND BACHELOR OF EDUCATION SCIENCE

PHYS: 134

INTRODUCTION TO QUANTUM MECHANICS

STREAMS: BSc, BEd

TIME: 2 HOURS

DAY/DATE: THURSDAY 13/04/2023

02:30 PM - 04:30 PM

INSTRUCTIONS:

Answer question ONE and any other TWO questions.

Clearly show your workings.

Useful constants

Mass of an electron, $m_e = 9.11 \times 10^{-31} kg$

Electron charge = $1.6 \times 10^{-19} C$

Plank's constant: $h = 6.63 \times 10^{-34} Js$, $\hbar = 1.05 \times 10^{-34} Js$

Speed of light, $c = 3.0 \times 10^8 m/s$

Permittivity, $\epsilon_0 = 8.85 \times 10^{-12} F/m$

$1eV = 1.6 \times 10^{-19} Joules$

QUESTION ONE 30 MARKS

- a) Explain the meaning of the term "Black body". (2 Marks)
- b) State the Heisenberg's uncertainty principle (3 Marks)
- c) Calculate the radius and energy of the electron in the n^{th} orbit in the hydrogen atom. (6Marks)
- d) Give a brief explanation of how X-rays are produced (4 Marks)
- d) Describe the Rutherford's experiment and give its findings. (6 Marks)
- e) X rays of wavelength $\lambda = 22 pm$ (photon energy = 56 keV) are scattered from a carbon target, and the scattered rays are detected at 85° to the incident beam. What is the Compton shift of the scattered rays? (4 Marks)
- f) Explain the failure of classical theory in the explanation of Compton effect (5 Marks)

QUESTION TWO 20 MARKS

- a) State the laws of photoelectric emissions (4 Marks)
- b) Ultra-violet light of wavelength 207 nm causes photoemission from a surface. The stopping potential

is 2V. Find

- i) The work function in eV. (3 Marks)
- ii) The maximum speed of the photoelectrons. (2 Marks)
- b) Explain the following phenomenons and highlight how classical theory failed to explain the observations.
 - i) Black body radiation (3 Marks)
 - ii) The Photoelectric effect (3 Marks)
 - iii) The Compton Effect (3 Marks)
 - iv) The Heat Capacity of Solids (2 Marks)

QUESTION THREE 20 MARKS

- a) Explain the meaning of
 - i) Particle annihilation (2 Marks)
 - ii) Particle creation (2 Marks)
- b) State and explain the similarities and differences between emission and absorption spectrums. (4 Marks)
- c) Using a schematic diagram, explain the working of a nuclear reactor for electricity generation. (8 Marks)
- d) X-rays of wavelength 0.24 nm are scattered through an angle of 40° as they pass a block of carbon. What is the wavelength of the scattered rays? (4 Marks)

QUESTION FOUR 20 MARKS

- a) What is the de Broglie wavelength of an electron accelerated from rest by a p.d of 50 V. (3 Marks)
- b) The work function of a particular metal is 2.0 eV.
 - i) If the metal is illuminated with a monochromatic light having a wavelength of 550 nm, what will be the maximum speed of the emitted electron? (6 Marks)
 - ii) What is the stopping potential? (3 Marks)
- c) Give the characteristics of X-rays and briefly explain how they are produced. (6 Marks)

QUESTION FIVE 20 MARKS

- a) Explain the Rutherford model of the atom (3 Marks)
 - b) State the postulates in the Bohr model of the atom giving relevant equations. (6 Marks)
 - c) Using the Bohr postulates show the formula for the radius of a stationary orbit is given by

$$r_n = \frac{n^2 \hbar^2}{m k e^2}. \quad (4 \text{ Marks})$$
 - d) Calculate the radius and energy of the electron in the n^{th} orbit in hydrogen atom. (Use the constants provided.) (7 Marks)
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