NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OFAPPLIED SCIENCES

DEPARTMENT OF APPLIED PHYSICS

BSc. (Hons) IN APPLIED PHYSICS   PART I

MODERN PHYSICS

SPH1104

First Semester Examination Paper

DECEMBER 2024

This examination paper consists of 4 pages

Time Allowed:	3 hours
Total Marks:	100
Special Requirements:	None
Examiner's Name:	Mrs T. Thatha

INSTRUCTIONS

ANSWER <u>ALL</u> PARTS OF QUESTION 1 IN SECTION A AND ANY <u>THREE</u> QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS.

MARK ALLOCATION

QUESTION	MARKS
1.	40
2.	20
3.	20
4.	20
5.	20
6.	20
Maximum possible mark	100

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Rydberg Constant	$R = 1.10 \times 10^7 m^{-1}$
Planck's constant	$h = 6.63 \times 10^{-34} Js$
Boltzmann constant	$k = 1.38 \times 10^{-23} J/K$
Avogadro's number	$N = 6.02 \times 10^{23} mol^{-1}$
Electron rest mass	$m_c = 9.11 \times 10^{-31} kg$
Speed of light	$c = 3.00 \times 10^8 ms^{-1}$
1 electron volt	$e = 1.60 \times 10^{-19} J$
Mass of electron	$m_e = 5.48 \times 10^{-4} u$
Mass of proton	$m_p = 1.007825 u$
Mass of neutron	$m_n = 1.008665 u$
1 atomic mass unit	$1u = 931.49 MeV/c^2$
Electron charge	$e = 1.60 \times 10^{-19} C$
Stefan − Boltzmann constant	$\sigma = 5.67 \times 10^{-8} W/m^2 K^4$
Wien's constant	$k = 2.90 \times 10^{-3} mK$
Wien's displacement law constant	$2.898 \times 10^{-3} mK$
Mean radius of the sun	$R_0 = 6.96 \times 10^8 m$
Mass of the sun	$m_{sun} = 1.99 \times 10^{30} kg$
Mass of ^6Li	$6.015122 u$
Mass of ^2H	$2.014102 u$
Mass of ^4He	$4.002603 u$
Mass of ^7Li	$7.016004 u$
Mass of ^8Be	$8.005305 u$
$1 Ci$	$3.70 \times 10^{10} Bq$

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SECTION A

1 (a) A 50W lamp emits red light with a wavelength, $\lambda = 7 * 10^{-7} m$. Calculate the number of photons emitted per second. [5]

   (b) i.   With the aid of a well labelled diagram, describe the photoelectric effect. [5]
        ii. For the photoelectric effect, define the following terms:
             a. Work function [2]
             b. Photoelectron [2]
             c. Threshold frequency and [2]
             d. Write down the photoelectric equation. [4]

   (c) Briefly explain the phase "wave-particle duality". [5]

   (d) i.   What is the 'Ultraviolet catastrophe"? [2]
        ii. For a blackbody at a temperature of 800K, find the wavelength of the most intense part of radiation that it emits. [3]

   (e) Differentiate between an emission line spectrum and an absorption line spectrum and explain how you would go about producing each. [10]

SECTION B

2. (a) i.   Briefly describe Compton's experiment and explain how it can be used as a basis to support the particle nature of electromagnetic radiation. [2]
         ii. Show, using diagrammatic illustrations, that the expression for the Compton shift, $\Delta\lambda$ is given by:
         $$\lambda^1 - \lambda = \frac{h}{m_e c}(1 - Cos\theta),$$
         where θ is the scattering angle of the photon. [10]

    (b) X-rays pf wavelength 10.0 pm are scattered from a target. Find:
         i.   The wavelength of the x-rays scattered through 45^0. [2]
         ii. The maximum wavelength present in the scattered x-rays. [2]
         iii. The maximum kinetic energy of the recoil electrons. [4]

3. (a) Write down the decay law and explain all the terms. [6]
    (b) State the three types of radiation and their penetrating abilities. [6]
    (c) Describe the following types of decay processes:
         i.   beta decay [2]
         ii. gamma decay [2]
         iii. alpha decay and [2]
         iv. electron capture. [2]

4. (a) The temperature of your skin is approximately 35 degrees Celsius.

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       i.   Assuming that it is a blackbody, what is the peak wavelength of the radiation it emits. [3]

      ii.   Assuming a total surface area of 2 square metres, what is the total power emitted by your skin? [3]

     iii. Based on your answer in b) why don't you glow as brightly as a light bulb? [2]

(b) State and describe the processes which result when a beam of radiation interacts with matter. [6]

(c) The following instruments are used for radiation monitoring, detection and measurement. Describe the operational principles of each.

      i.   Scintillators [2]

      ii.   Semiconductors and [2]

     iii. Ionization chambers. [2]

5   (a)   i.   What do you understand by the terms: *nuclear binding energy* and *mass defect*? [4]

      ii.   Calculate the binding energy of a deuterium, ^2_1H nucleus and hence, [3]

     iii. Find the binding energy per nucleon. [3]

(b) A gas of $^{222}_{86}Rn$ decays by α- emission with a half-life of 3.82 days

      i.   Write an equation for the disintegration of this radio nuclide. [3]

      ii.   How long does it take for 60 % of the sample to decay? [3]

     iii. What is the activity after one week if 1.00 mg of $^{222}_{86}Rn$ were confined in a closed container. [4]

6   (a)   State Bohr's assumptions for the theory of the hydrogen atom [4]

   (b)   Using the Bohr's assumptions stated above show that:

     1. The velocity of an electron in orbit is

$$V = \frac{nh}{m_e r 2\pi}$$

[5]

     2. Show that the total energy of the electron in the nth orbit is given by

$$E_n = -\frac{Ke^2}{2r_n}$$

[5]

     3. The radius for the nth orbit of Bohr's model of the hydrogen atom is given by

$$r = \frac{n^2 h^2}{4\pi^2 m_e Ke^2}$$

[6]

END OF EXAMINATION PAPER

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