NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF SCIENCE AND TECHNOLOGY EDUCATION

DEPARTMENT OF SCIENCE, MATHEMATICS AND TECHNOLOGY EDUCATION

BACHELOR OF SCIENCE HONOURS DEGREE IN PHYSICS EDUCATION

OPTICS AND MODERN PHYSICS (PST 2174)

Main Examination Paper

November 2024

This Examination Paper consists of 5 printed pages

Time allowed :3 hours

Total Marks :100

Special requirements :None

Internal Examiner :J Hlongwane

External Examiner : Dr Zezekwa

INSTRUCTIONS

1. Answer **all** questions in section **A** and any three questions in section **B**

(Section A carries 40 marks and section B carries a total of 60 marks).

2. Show all your work clearly in any calculation.

3. Start the answer for any question on a new page.

MARK ALLOCATION

QUESTION	MARKS
1	40
2	20
3	20
4	20
5	20
TOTAL	100

DATA

Plank's constant	$h = 6.63\times 10^{-34}$ J.s
Electron rest mass	$m = 9.11\times 10^{-31}$ Kg
Speed of light	$c = 3.00\times 10^{8}$ m/s
1 electron volt	$e = 1.60 \times 10^{-19}$ J
Mass of electron	$m_e = 5.48 \times 10^{-4}$ u
Mass of proton	$m_p = 1.007\ 825$ u
Mass of neutron	$m_n = 1.008\ 665$u
1 atomic mass unit	$1u = 931.49$ Mev/c^2
Electronic charge	$e = 1.60 \times 10^{-19}$C
Stefan – Boltman constant	sigma = 5.67×10^{-8} W/m^2 . K
Boltzmann constant	$K_B = 1.380649 \times 10^{-23} JK^{-1}$
Wien constant	$k = 2.899 \times 10^{-3}$ m. K
Mass of Helium	^{4}He = 4.002 603 u
Mass of Oxygen	$^{16}_{8}$O = 15.9994U
Mass of Hydrogen	^{1}H = 1.007 825 u
Radius of Earth	$R_E = 6.37 \times 10^6$ m

SECTION A

1. a. Light from water with a refractive index of 1.33 travels into a type of glass with a refractive index of 1.55. The system is held at a constant temperature of 303K. Draw a labelled ray diagram and calculate the angle of refraction if the incident angle is 36^0. [3]

   b. Redesign the system in 1(a) to enable TIR to occur and hence calculate the critical angle of the system. [5]

   c. Determine the De Broglie wavelength of an electron travelling in a vacuum at a constant speed approximately 90% of the speed of light [3]

   d. Describe the photoelectric effect (include illustrative diagrams) and explain why Einstein's photo-electric equation is a principle of conservation of energy. [9]

e. Outline how the knowledge of modern Physics can be applied in the production of any type of named renewable energy. [7]

f. Briefly describe Compton's experiment with reference to Fig 1.1 and explain how it can be used as a basis to support the particulate nature of electromagnetic radiation. [6]

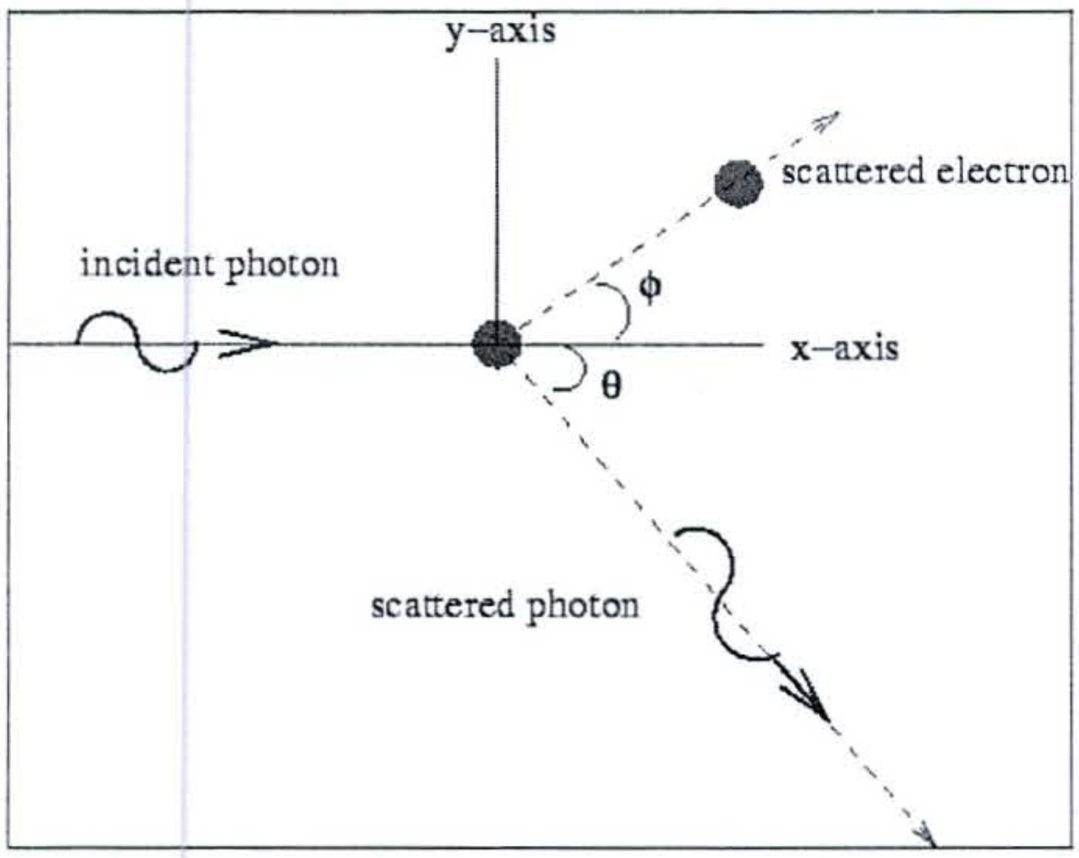

Fig 1.1

g. Copy Fig 1.2 and label all important points and angles, use it to explain how a rainbow is formed in the sky. Your account should include refractive indices and angles of refraction and reflection and TIR. [8]

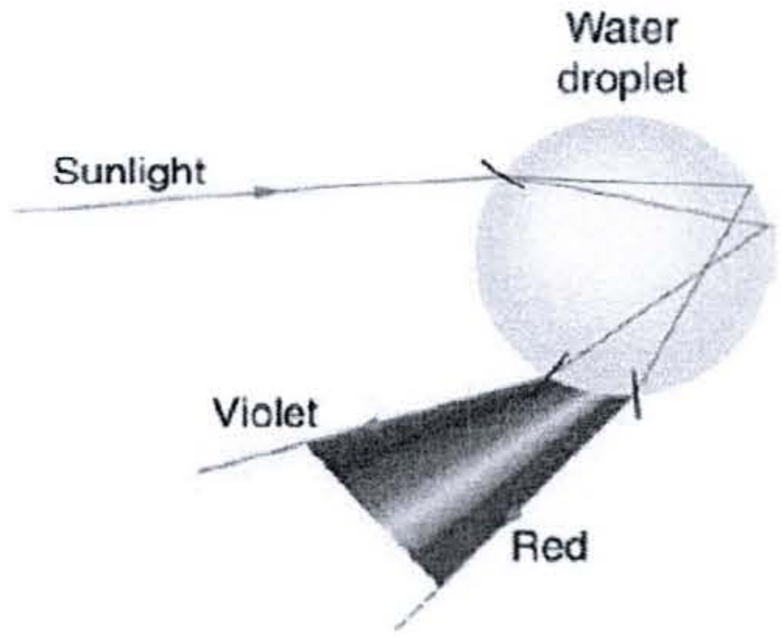

Fig 1.2

SECTION B

2. a. The intensity spectrum at any angle for a photon-electron interaction has at least two characteristic peaks as shown in Fig 2.1. Explain the two peaks with respect to the Compton Effect. [5]

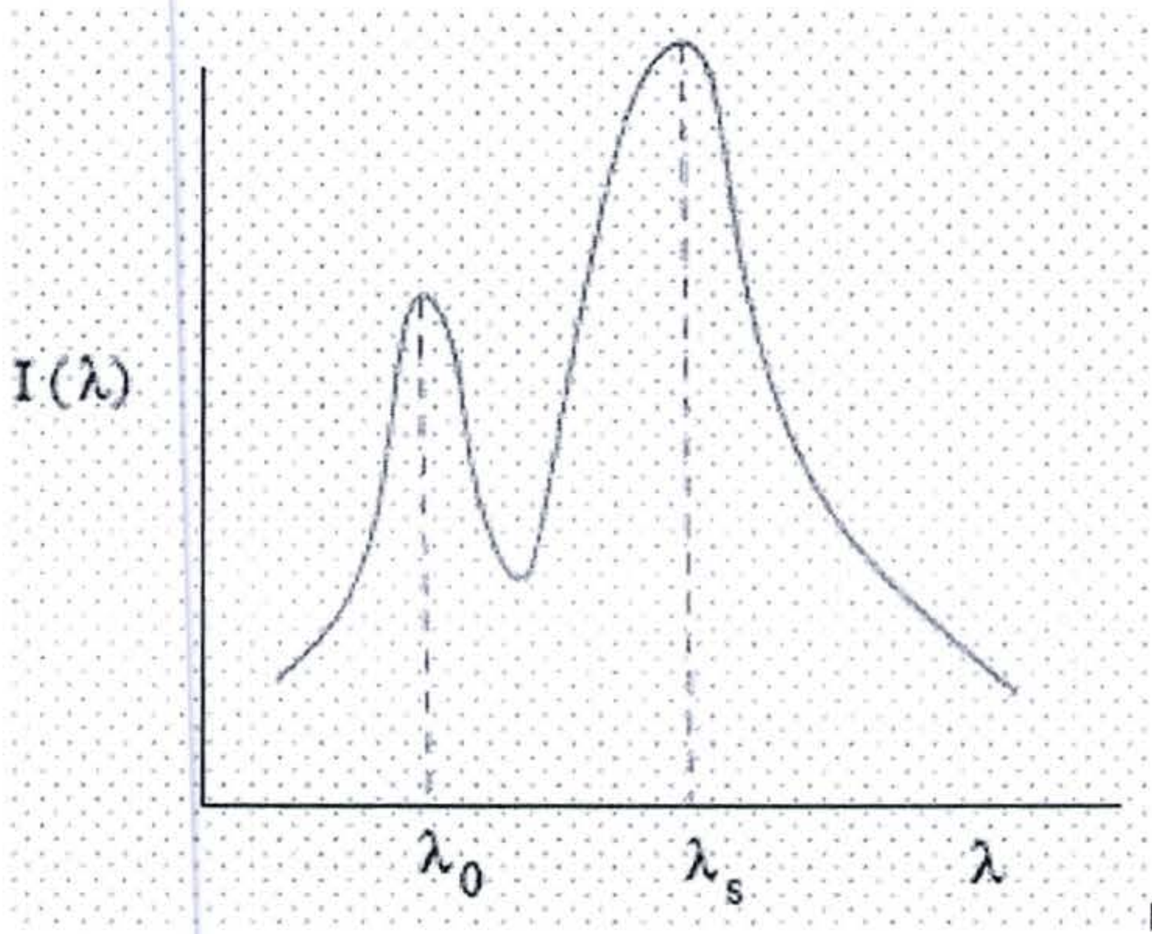

Fig 2.1

b. A gold nucleus contains 79 protons and 118 neutrons. The mass of gold nucleus = 196.923180u, Mass of a proton = 1.007276u, Mass of a neutron = 1.008665u.

Write a balanced equation and Calculate the energy required to split the nucleus(in MeV). [4]

c. Calculate the Binding energy per nucleon of gold. [4]

d. Use ray diagrams on Fig 2.2 to locate the image of the object (draw the diagram to real scale). [7]

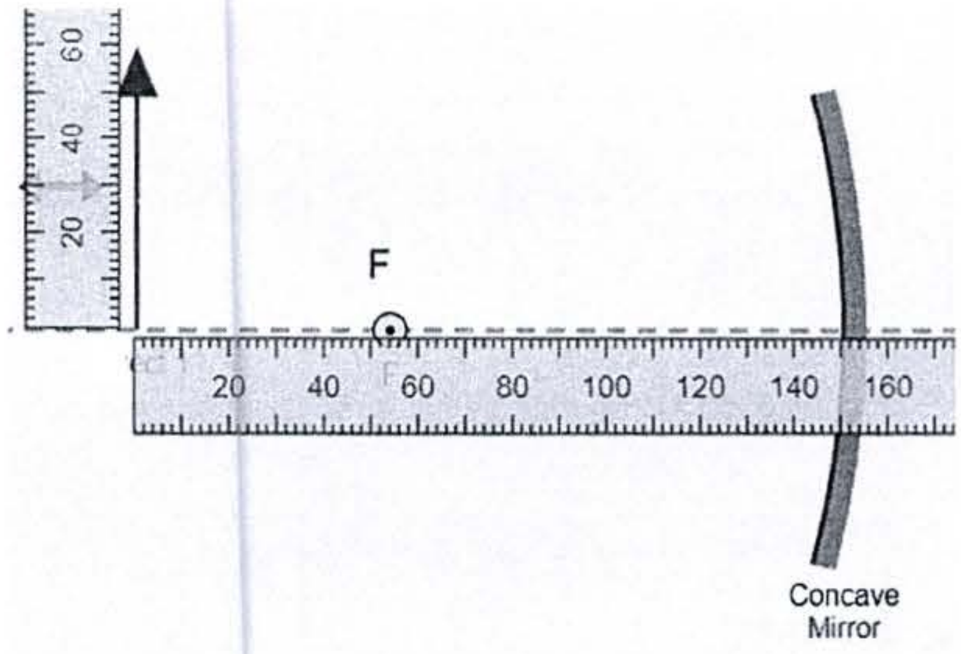

Fig 2.2

3. a. Describe how concave spectacles are used to correct a named eyesight defect. [6]

b. Calculate the threshold frequency of a metal with a work function of 10eV. [4]

c. Discuss four aspects of real life in which optical Physics has a large impact. [10]

4. a. Use Fig 4.1 to explain the ultraviolet catastrophe and how it was resolved. [5]

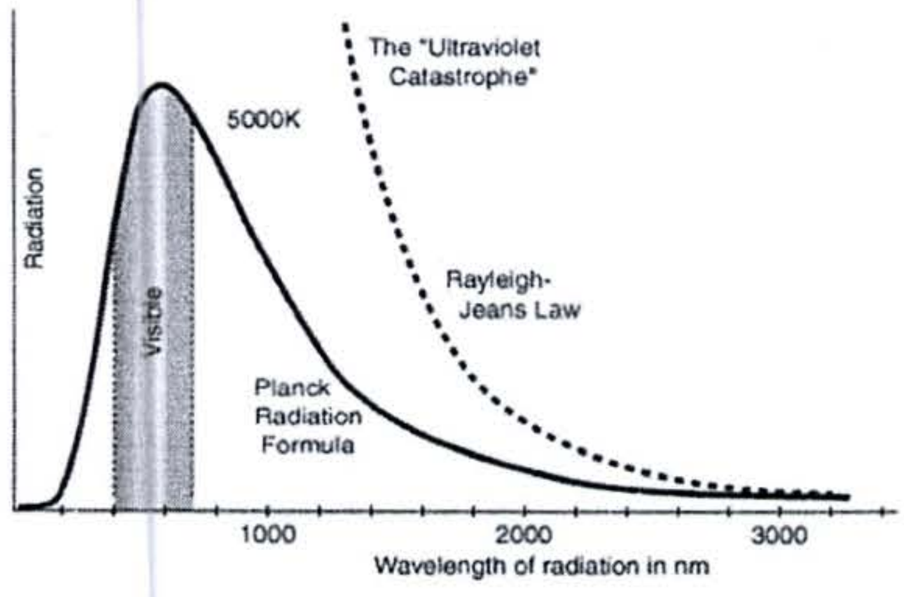

Fig 4.1

b. On Fig 4.1, add three more peaks at temperatures less than 5000K to explain black body radiation. [5]

c. The sun is a black body. Discuss what this means and how 'clean' solar energy is produced to power electronic gadgets. [7]

d Calculate the peak wavelength for a radiation at a temperature of 3000K. [3]

4. a. With reference to Fig 4.1, identify the process shown and deduce the nuclear equation for the reaction. [4]

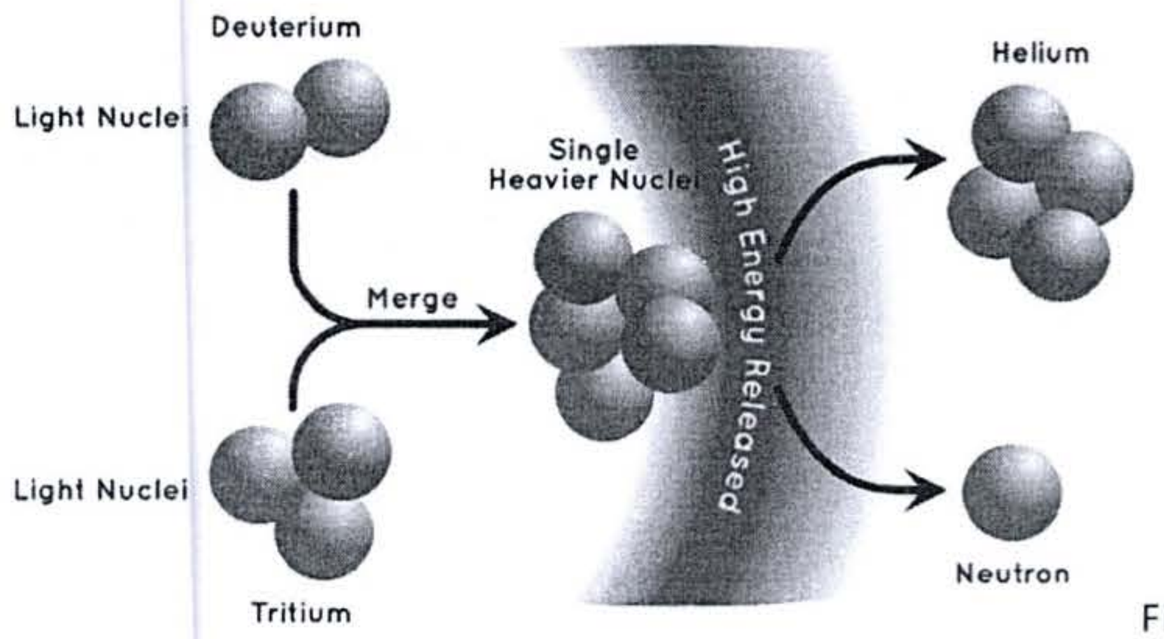

Fig 4.1

b. Outline where the reaction in Fig 4.1 naturally occurs, stating the major conditions and at least two applications of the nuclear energy produced. [6]

c. Determine the change in a photon's wavelength that occurs when an electron scatters an x-ray photon at: 180^0 and at $30^{0'}$ [6]

d Use ray diagrams to explain how Total Internal Reflection occurs. [4]

END OF EXAMINATION