BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE EDUCATION

DEPARTMENT: SCIENCE AND MATHEMATICS EDUCATION

DIPLOMA IN SCIENCE EDUCATION

DP005/PH004 (1): MODERN PHYSICS

DURATION: 3 HOURS TOTAL MARKS: 100

INSTRUCTIONS TO CANDIDATES

Answer all questions in Section A and any three (3) questions from Section B

SECTION A (40 Marks)

Answer all questions

APR 2025

QUESTION 1 [40 MARKS]

a) Define the terms
   i. isotopes (2)
   ii. photon. (2)
b) What is the atomic number of an element with 12 protons in its nucleus? (2)
c) How does the de Broglie hypothesis explain the behaviour of electrons in an atom? (3)
d) What is the difference between alpha and beta decay? (2)
e) Calculate the;
   i. momentum of a photon with a frequency of 9.65×10^{14}Hz. (5)
   ii. binding energy per nucleon in the calcium-40 ($^{40}_{20}Ca$) nucleus. (10)
f) Niels Bohr introduced the atomic Hydrogen model as a positively charged nucleus, comprised of protons and neutrons, surrounded by a negatively charged electron cloud. In the model, electrons orbit the nucleus in atomic levels.
   i. Explain the difference between the Lyman, Balmer, and Paschen series in the hydrogen atom spectrum. (6)
   ii. Calculate the wavelength of the radiation emitted when an electron transitions from the fifth energy level (n=5) to the third energy level (n=3) in a hydrogen atom. (6)
   iii. Identify the spectral series. (2)

SECTION B (60 Marks)

Answer any three (3) questions

QUESTION 2 [20 MARKS]

a) The following data shows the variation of Compton shift with scattering angle for a photon beam:

Scattering Angle (°)	Compton Shift (nm)
30	2.0
45	3.5
60	5.0
90	7.0
120	8.5

Plot a graph of Compton shift versus scattering angle and discuss the results.(12)

b) Calculate the energy transferred to an electron in a Compton scattering event, given the incident photon energy is 2.5 eV and the scattering angle is 60°.(5)

c) Explain the significance of the Compton effect in understanding the nature of light. (3)

QUESTION 3 [20 MARKS]

The photoelectric effect is a low-energy phenomena while on the other hand the Compton effect is a mid-energy phenomenon;

a) Explain the concept of the photoelectric effect. (2)

b) What is the significance of the threshold frequency in the photoelectric effect? (1)

c) Draw a well labelled diagram illustrating the photoelectric effect. (1 mark)

d) A metal surface has a work function of 2.5 eV;

   i. What is the maximum kinetic energy of electrons emitted when light of wavelength 400 nm is incident on it? (3)

   ii. What is the stopping potential required to stop the electrons emitted? (1)

   iii. Explain why the stopping potential is independent of the intensity of the incident light. (1)

   iv. Derive the equation for the maximum kinetic energy of electrons emitted in the photoelectric effect. (3)

   v. What is the significance of the slope of the graph between KE and frequency of incident light? (2)

   vi. How does the graph change if the intensity of incident light is increased? (1)

e) Explain the difference between the photoelectric effect and Compton scattering. In your account, identify the phenomenon between the two that is best suited for studying the wave nature and particle nature light? (5)

QUESTION 4 [20 MARKS]

A sample of the isotope ^{131}I, which has a half-life of 8.04 days, has an activity of 5 mCi at the time of shipment. Upon receipt of the ^{131}I in a medical laboratory, its activity is 4.2 mCi.

Hint: One curie (1 Ci) is equal to 3.7×10^{10} radioactive decays per second.

a) Define the term 'half-life' (2)

b) How much time has elapsed between the two measurements? (10)

c) A radioactive sample contains 3.50μg of pure $^{11}_{6}C$ which has a half-life of 20.4 min. What is the activity of the sample initially and after 8.00 hours? (8)

QUESTION 5 [20 MARKS]

Millikan carried out a series of experiments using oil drops that contributed immensely to Physics.

a) With the aid of a clearly labelled sketch describe Millikan's experiment. What was its physical significance? (8)

b) In an oil drop experiment similar to Millikan's, an oil drop is suspended between two parallel charged plates. Calculate the magnitude of the charge on the oil droplet if the radius of the oil drop is $4.2 \times 10^{-6} m$, the density of the oil is $7.8 \times 10^{2} gm^{-3}$, the distance between the plates is $2.0cm$, and the potential difference between the plates is $99V$, the distance between the plates is $2.0cm$, and the potential difference between the plates is $99V$. (6)

c) During a Millikan oil-drop experiment, a student records the weights of five different oil drops. The student also records the electric field intensity necessary to hold each drop stationary between the two horizontal parallel plates.

$Weight \times 10^{-14} N$	1.7	5.6	6.1	2.9	4.0
$\vec{E} \times 10^{5} N C^{-1}$	1.1	3.5	3.8	1.8	2.5

Using $\vec{E}$ as the manipulated variable, draw a graph showing the relationship between the weight and the electric field. Using your graph determine the elementary charge. (6)

Some useful constants

Planck's constant,	$h = 6.63 \times 10^{-34} Js$
Speed of light,	$c = 3 \times 10^{8} 8 ms^{-1}$
Speed of sound in air	$v = 3 \times 10^{8} 8 ms^{-1}$
Charge of an electron	$e = 1.602 \times 10^{-19} C$

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