BINDURA UNIVERSITY OF SCIENCE EDUCATION

Faculty of Science Education

Department of Science and Mathematics Education

MAR 2024

Diploma in Science Education (Physics)

PH004

Modern Physics

Duration: Three (3) Hours

INTSRUCTIONS

- *Answer ALL questions in Section A and any THREE questions from Section B. Section A carries 40 marks and each question of Section B carries 20 marks.*
- *Show ALL formulae and substitutions in ALL calculations.*
- *Show the degree of accuracy in all numerical answers e.g 2 dp for 2 decimal places or 2 sf for 2 significant figures.*

You may not start to read the questions printed on the subsequent pages until instructed to do so by the Invigilator.

SECTION A (40 Marks)

QUESTION 1 [40 MARKS]

a) One mole of a radioactive substance starts to decay. How many radioactive nuclei will be left after $t = T_{1/2}$? (3)

b) An atomic oscillator emits radiation of 700.0-nm wavelength.

i. Define the term 'photon'. (2)

ii. How much energy is associated with a photon of radiation of this wavelength? (5)

iii. Calculate the wavelength of a photon that has $1.50eV$ of energy? (5)

iv. Find the mass of a photon of light that has a wavelength of 720.0 nm. (5)

c) Consider the following questions on waves;

i. Briefly explain the de Broglie hypothesis and its significance to Modern Physics. (4)

ii. Calculate the wavelength of a 50 kg athlete running at 16 m/s. (5)

d) Deuterium is one of two stable isotopes of hydrogen whose nucleus is known as the deutron. The mass of a proton is 1.6726×10^{-27} kg and the mass of a proton is 1.6749×10^{-27} kg. The experimental mass of the deuteron is 3.3435×10^{-27} kg. Find the;

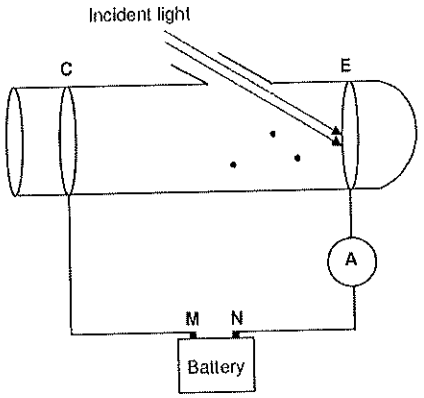
i. mass defect (5)

ii. the binding energy of the deuteron in mega electron volts (MeV) (6)

SECTION B (60 Marks)

QUESTION 2 [20 MARKS]

A photocell is set up as shown to investigate the photoelectric effect. Metal plate E (cathode) and C (anode) are connected to the terminals of a battery. An ammeter A is connected in series with the battery.



a) What is meant by the photoelectric effect? (2)

b) Which terminal of the battery must be the positive one to record a possible current? Write only M or N. Give a reason for your answer (3)

The cathode is made up of silver metal with a work function of $7{,}42\ x\ 10^{-19}\ J$. Monochromatic light of wavelength 300 nm is incident on the cathode of the photoelectric tube.

c) Define the term work function. (2)

d) Explain what happens to the ammeter reading when the monochromatic light is incident on the cathode? Support your answer with relevant calculations. (8)

e) Another frequency of light is incident on the photocell and an ammeter reading is registered. How will increasing THE INTENSITY of the incident light affect each of the following? Write down only INCREASE, DECREASE or REMAIN THE SAME.

i. Number of electrons emitted per unit time. Give a reason for your answer in each case (4)

ii. The kinetic energy of the photoelectrons (1)

QUESTION 3 [20 MARKS]

In a Compton scattering event, the scattered photon has an energy of 120 keV and therecoiling electron has an energy of 40 keV. Find

a) the wavelength of the incident photon. Leave your answer in angstroms (Hint: one angstrom (Å) is equal to 10^{-10}m), (6)

b) the angle at which the photon is scattered, and (7)

c) the recoil angle φ of the electron. (7)

QUESTION 4 [20 MARKS]

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)

QUESTION 5 [20 MARKS]

Some radioactive isotopes can emit 3 types of radioactivity A, B and G.

a) Define the term 'isotope'. (2)

b) Complete the table below showing the properties of the three types of radioactivity: (6)

Type of radioactivity:	Nature:	Charge:	Ionising power:	Penetrating power:
A	(i)	+2	large	Thin sheet of paper
B	(ii)	(iii)	medium	(vi)
G	Electromagnetic waves	(iv)	(v)	Many cm of lead

c) The half-life of strontium-90 ($^{90}_{38}Sr$) is 28.8 yr. Find its decay constant and activity for 1 g of the material. (12)

THE END

Some useful constants

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