BINDURA UNIVERSITY OF SCIENCE EDUCATION

Faculty of Science and Engineering

Department of Engineering and Physics

Diploma in Science Education (Physics)

PH004

Modern Physics

Duration: Three (3) Hours

Answer <u>ALL</u> parts of Section A and any <u>THREE</u> questions from Section B.
Section A carries 40 marks and each question of Section B carries 20 marks.

Clearly show <u>ALL</u> working

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

SECTION A

Attempts all parts of question 1

(i) (a) An alpha particle travels through a magnetic field of $4.22 \times 10^{-1}\ T$ perpendicularly to the field. If the radius of the arc of the deflected particles is $1.5 \times 10^{-3}\ m$, calculate the speed of the particles. (5)

(b) A $5.70 \times 10^{-16}\ kg$ oil drop accelerates upward at a rate of $2.90\ ms^{-2}$ when placed between two horizontal plates that are $3.50\ cm$ apart. If the potential difference between the plates is $7.92 \times 10^{2}\ V$, how many excess electrons does the oil drop carry? (5)

(c) Electrons are emitted from a photoelectric surface with maximum energy of $2.9\ eV$. If the photons of the light have $3.45\ eV$ of energy, what is the minimum frequency of light that can be used to emit electrons? (5)

(d) How many protons and neutrons are found in the nucleus of the following isotopes?

(i) $^{16}_{8}O$ (1)

(ii) $^{35}_{17}Cl$ (1)

(iii) $^{234}_{92}U$ (1)

(iv) $^{234}_{90}Th$ (1)

(v) $^{1}_{1}H$ (1)

(e) The mass of a carbon-14 nucleus is $2.3252 \times 10^{-26}\ kg$. Find the:

(i) mass defect of the carbon-14 nucleus; and the (3)

(ii) binding energy of the carbon-14 nucleus. (2)

(f) Complete the following nuclear reactions:

(i) $^{226}_{88}Ra \longrightarrow {}^{222}_{86}Rn + ?$ (1)

(ii) $^{46}_{24}Cr \longrightarrow {}^{0}_{1}\beta + ? + ?$ (2)

(iii) $^{214}_{83}Ra \longrightarrow {}^{214}_{84}Po + ? + ?$ (2)

(g) If the half-life of an isotope is 3.0 days, what percentage of the isotope will remain after 2.5 days? (5)

(h) Complete the following nuclear reactions:

(i) $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{90}_{38}Sr + ? + 3{}^{1}_{0}n$ (2.5)

(ii) $^{6}_{3}Li + ? \longrightarrow 2{}^{4}_{2}He$ (2.5)

SECTION B

Attempts any three (3) questions

2. (a) With the aid of a clearly labelled diagram describe Millikan's oil drop experiment. What was its physical significance? (10)

(b) In a Millikan oil drop experiment, a student sprayed oil droplets with a density of $7.8 \times 10^2 kgm^{-3}$ between two horizontal, parallel plates that were 4 cm apart. The student adjusted the potential difference between the plates to $4.6 \times 10^3\ V$ so that one of the drops became stationary. The diameter of this drop was measured to be $2.4 \times 10^{-6}\ m$. What was the magnitude of the charge on this oil drop? (5)

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

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

(i) Using $\vec{E}$ as the manipulated variable, draw a graph showing the relationship between the weight and the electric field. (3)

(ii) Using only your graph, determine the elementary charge. (2)

3. (a) With the aid of a clearly labelled sketch describe the photoelectric effect (PE) experiment. What was its physical significance? (8)

(b) Electromagnetic radiation (EMR) with a frequency of $7.52 \times 10^{14}\ Hz$ illuminates a photoelectric surface in a photoelectric cell. If the work function of this surface is 2.20 eV, what stopping potential would be required to reduce the current through this cell to zero? (4)

(c) During a PE experiment a student records the frequency (ν) of EMR and the maximum kinetic energy (E_K) of the photoelectrons.

ν $(\times 10^{14}\ Hz)$	E_K $(\times 10^{-19}\ J)$
6.2	2.56
5.3	2.00
4.2	1.31
3.5	0.90
2.9	0.45

(i) Draw a graph to show the relationship between the frequency of the incident EMR and the maximum kinetic energy of the photoelectrons. (3)

(ii) Using only your graph, find the threshold frequency and Planck's constant. (5)

4. (a) Briefly outline Compton's experiment. What was its significance? (5)

(b) X-rays of wavelength 0.2 nm are scattered by some material. The scattered electromagnetic radiation (EMR) is detected at 45.0^0 to the incident beam. Find the wavelength of the scattered EMR. (5)

(c) Discuss the de Broglie hypothesis. (5)

(d) For a proton which has been subjected an accelerating potential of 15 V, calculate its de Broglie wavelength. (5)

5. (a) For this question you are provided with the following masses:

$$^{239}Pu = 396.92935 \times 10^{-27}\ kg$$

$$^{142}Ba = 235.64216 \times 10^{-27}\ kg$$

$$^{93}Sr = 154.27837 \times 10^{-27}\ kg$$

$$n = 1.67493 \times 10^{-27}\ kg$$

Plutonium (Pu) is used as fuel in a nuclear reactor to generator energy. The following equation shows a fission reaction of plutonium that releases energy:

$$^{239}_{94}Pu + {}^{1}_{0}n \longrightarrow {}^{142}_{56}Ba + {}^{93}_{38}Sr + 5{}^{1}_{0}n$$

Calculate the amount of energy, in electron volts (eV), generated in this reaction. (15)

(b) The following data about a sample of a radioactive isotope are given:

Activity ($\times 10^5\ Bq$)	Time (min)
7.00	0
5.31	2.0
4.02	4.0
3.05	6.0
2.31	8.0
1.75	10.0

(i) Draw an activity-time graph for the given sample. (3)
(ii) Using your graph, determine the half-life of the isotope. (2)

6. (a) Describe (with the aid of sketches) the following models of the hydrogen atom:

(i) Plum-pudding model; (5)
(ii) Rutherford's Planetary model. (5)

(b) Figure 1 illustrates Bohr's model of the hydrogen atom.

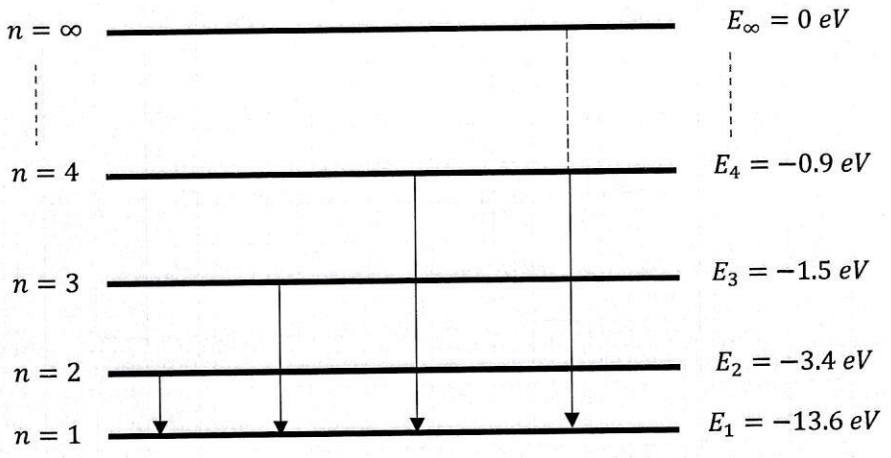

Figure 1

(i) Using the given diagram explain Bohr's model of the hydrogen atom. (5)
(ii) Find the frequency and wavelength of the photon emitted as an electron moves from the fourth level to the third level. (5)