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 ALL parts of Section A and any THREE questions from Section B.
Section A carries 40 marks and each question of Section B carries 20 marks.

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

Physical constants

Rest mass of electron $m_e = 9.11 \times 10^{-31}$ kg
Acceleration due to gravity $g = 9.81 ms^{-2}$
Speed of light $c = 3 \times 10^8 ms^{-1}$
Charge of electron $e = 1.6 \times 10^{-19}$ C
Atomic mass unit $u = 1.66 \times 10^{-27}$ kg
Planck's constant $h = 6.63 \times 10^{-34}$ Js
1eV $= 1.6 \times 10^{-19}$ J
Mass of $^4_2He = 4.002604u$
Avogadro's number $N_A = 6.02 \times 10^{23}$

SECTION A

Attempt all parts of question 1.

1. (a) What is the wavelength of a photon that has 1.50 eV of energy?

[2]

(b) Calculate the wavelength of an electron moving at $1.0 \times 10^6 ms^{-1}$.

[3]

(c) Write brief notes on alpha, beta and gamma decay.

[15]

(d) Complete the following **fission reactions**:

$$^{235}_{92}U + \ ^1_0n \rightarrow \ ^{90}_{38}Sr + ? + 3\,^1_0n$$

$$^{235}_{92}U + \ ^1_0n \rightarrow \ ^{107}_{43}Te + ? + 5\,^1_0n$$

[5]

(e) Complete the following **fusion reactions**:

$$^6_3Li + ? \rightarrow \ 2\,^4_2He$$

$$^{16}_{8}0 + \ ^2_1H \rightarrow ? + \ ^4_2He$$

[5]

(f) A 6.20×10^{-16} kg oil drop accelerates downward at a rate of 14.0 ms^{-2} when placed between horizontal, parallel plates that are 3.20 cm apart. If the potential difference between the plates is 175 V, what is the magnitude of the charge on the oil drop?

[5]

(g) Light with a wavelength of 425 nm illuminates a photoelectric surface that has a work function of 2.0 eV. What is the maximum speed of the emitted electrons?

[5]

SECTION B

Attempt any three questions.

2. (a) Describe (with a clearly labelled sketch) Millikan's Oil drop Experiment and explain its significance.

[7]

(b) An oil drop weighing $3.84 \times 10^{-15} N$ is suspended between two horizontal, parallel plates where the electric field strength is $1.20 \times 10^{4} NC^{-1}$. What is the magnitude of the charge on the oil drop?

[2]

(c) In a Millikan oil-drop experiment, a BUSE student sprayed oil droplets with a density of $7.8 \times 10^{2}\ kgm^{-3}$ between two horizontal, parallel plates that were 4.0 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?

[6]

(d) During the Millikan oil-drop experiment, the 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.

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

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

[3]

(ii) Using your graph determine the elementary charge.

[2]

3. (a) Describe (with the aid of a clearly labelled sketch) the photoelectric effect. Briefly explain its physical significance.

[7]

(b) When radiation with a wavelength of 215 nm illuminates a photoelectric surface in a photoelectric cell, a stopping voltage of $9.11 \times 10^{-1} V$ is needed to reduce the current through the cell to zero. What is the work function of the surface used in this cell?

[6]

(c) In a photoelectric experiment, a student obtained the data shown:

Frequency of Radiation $(\times 10^{14} Hz)$	9.9	7.7	4.7	3.2	2.3
Stopping Voltage (V)	4.10	2.95	1.45	0.70	0.15

(i) Draw a graph to show the relationship between the frequency of the incident radiation and the stopping voltage.

[3]

(ii) Using only your graph, calculate the threshold frequency of the incident radiation and Planck's constant.

[4]

4. (a) Clearly describe **ONE** problem associated with a planetary structure of the atom, with electrons revolving about the nucleus.

[3]

(b) Define the term emission spectrum.

[2]

(c) State Bohr's postulates.

[5]

(d) Figure 1 shows the energy level diagram for the hydrogen atom.

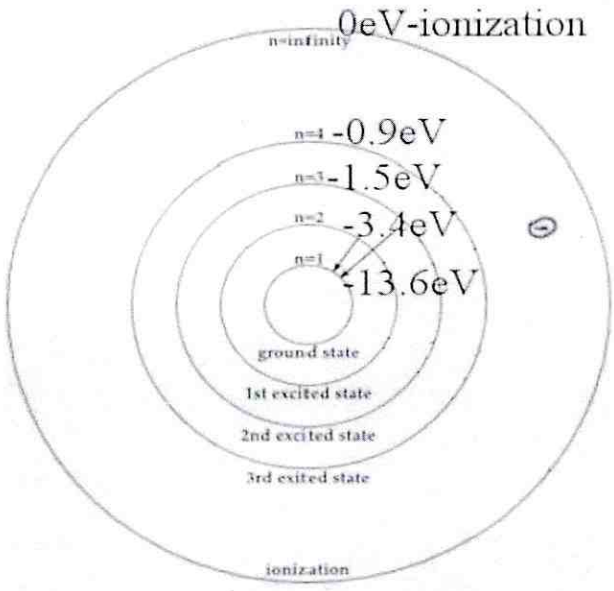

Figure1 Hydrogen atom energy levels

(i) Determine the frequency of the photon emitted as an electron moves from the fourth level to the third level.

[5]

(ii) What is the ionization energy of the third level? Hence determine the electron velocity.

[5]

5. (a) Define the following terms: (i) atomic mass (ii) isotope (iii) ions.

[6]

(b) Calculate the number of protons, neutrons and atomic mass of the fluorine atom, , ${}^{19}_{9}F$.

[3]

(c) Briefly explain the concepts of strong nuclear force and binding energy.

[6]

(d) The following atomic masses are given:

$$^{235}U = 3.9029 \times 10^{-25}\ kg$$
$$n = 1.6749 \times 10^{-27}\ kg$$
$$^{140}Xe = 2.3234 \times 10^{-25}\ kg$$
$$^{94}Sr = 1.5595 \times 10^{-25}\ kg$$

Determine the energy produced in the following fission reaction:

$$^{235}_{92}U + \ ^{1}_{0}n \rightarrow \ ^{140}_{54}Xe + \ ^{94}_{38}Sr + 2\,^{1}_{0}n$$

[5]

6. (a) Explain the terms transmutation and half-life.

[4]

(b) State the similarities and differences between the fission and fusion.

[6]

(c) 4.0 g of a neptunium is produced on Monday. On Tuesday of the following week it was tested and found that 0.25 g were remaining. Calculate the half-life of neptunium.

[5]

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

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