BINDURA UNIVERSITY OF SCIENCE EDUCATION

PHYSICS AND MATHEMATICS DEPARTMENT

PH004: MODERN PHYSICS E - MAY 2018

DURATION: THREE HOURS

Answer **ALL** parts of Section A and any **THREE** questions from Section B. Section A carries 40 marks and Section B carries 60 marks.

Proton	1.672621×10^{-27} kg
Neutron	1.674927×10^{-27} kg
Electron	0.000911×10^{-27} kg
Barium-141	233.9450×10^{-27} kg
Calcium-40	66.34121×10^{-27} kg
Krypton-92	152.6167×10^{-27} kg
Potassium-40	66.34446×10^{-27} kg
Uranium-235	390.2182×10^{-27} kg

Planck's constant	: 6.63×10^{-34} Js
Speed of light	: 3×10^{8} ms^{-1}
Charge on an electron	: 1.602×10^{-19} C
Gravitational acceleration	: 9.81 ms^{-2}
Avogadro's number	: 6.02×10^{23}

SECTION A

1. a. Explain in terms of binding energy, why the mass of Uranium-235 nucleus is less than the total mass of the constituent nucleons [8]

   b. Assume that a certain 660 Hz tuning fork can be considered as a harmonic oscillator whose vibrational energy is 0.04 J. Compare the energy quanta of this tuning fork with those of an atomic oscillator that emits and absorbs orange light whose frequency is 5×10^{14} Hz. [8]

   c. The work function of sodium is 2.28 eV. Calculate the threshold frequency for the emission of photoelectrons from the surface of sodium metal. [4]

   d. Given that the value of the *Rydberg constant R* (for hydrogen) is approximately 1.097×10^{7} m^{-1}, find the wavelength of the first line of the *Balmer* series. [5]

e. The helium isotope ${}^{6}_{2}He$ is unstable. What kind of decay would you expect it to undergo? [5]

f. Find the density of the ${}^{12}_{6}C$ nucleus. [4]

g. A 6.20×10^{-16} kg oil drop accelerates downward at a rate of $4.0\ ms^{-2}$ 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? [6]

SECTION B

2. A Hydrogen atom has the following characteristics: electronic charge (e), space permittivity (ε_0) and a radius of the orbit (r). With an aid of diagrams, clearly show that the total energy of a Hydrogen electron is given by Equation 2.1. Describe in detail all the terms used in the derivation. [20]

$$E_T = -\frac{e^2}{8\pi\varepsilon_0 r} \quad \text{..... (2.1)}$$

3. Fission reactions take place in a nuclear reactor when moving neutrons hit Uranium-235 nuclei. In one of the possible fission reactions, one neutron hits a nucleus and breaks into Krypton-92 Barium-141

a. Write a nuclear equation for the reaction and the other particles produced during the reaction [5]

b. If the moving neutron has kinetic energy $7.\times10^{-16}$ J, show that this energy contributes negligible mass to the mass of the moving electron [3]

c. If all the energy released from the fission of Uranium-235 nucleus is converted to a single photon, calculate the frequency of the photon produced. [8]

d. Calculate the total binding energy of the Uranium-235 nucleus [4]

4. a. Using a detailed diagram describe the photoelectric effect experiment and its major contributions to modern physics. [20]

5. a. i. With an aid of clearly labelled diagram, discuss Rutherford's nuclear atomic model. [6]

ii. What are its drawbacks? [6]

b. Calculate the binding energy per nucleon in the Potassium-40 nucleus [8]

6. Figure 6.1 illustates the Bohr model of the hydrogen atom.

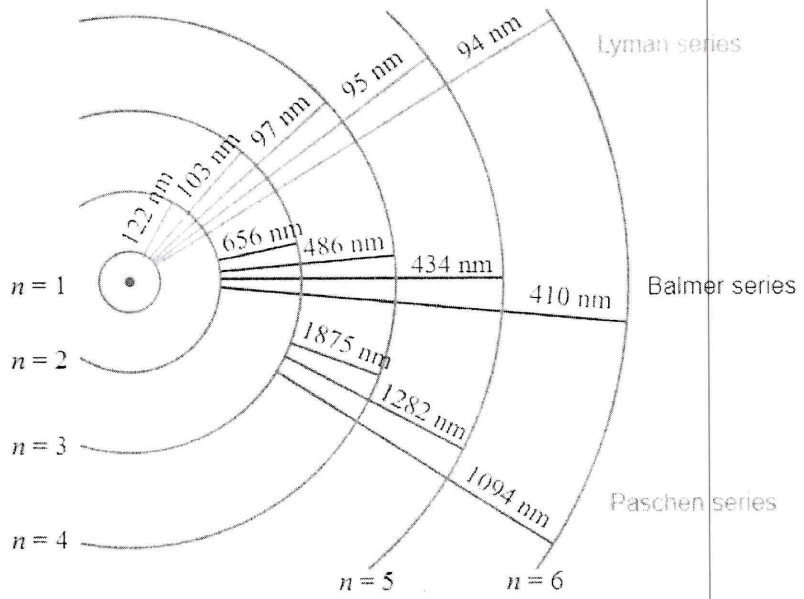

Figure 6.1: Question 6

a. Explain what the circles and lines represent. [2]

b. Explain how this model explains emission line spectra and absorption line spectra caused by hydrogen. [6]

c. The line between $n = 5$ and $n = 2$ is labelled 434 nm. Show that this is correct for a Hydrogen atom. [6]

d. Calculate the energy of a hydrogen atom in its ground state. Express your answer in eV. [6]

END OF PAPER