DEPARTMENT OF PHYSICS
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2005/2006 HARMATTAN SEMESTER EXAMINATIONS

PHY 203 Elementary Modern Physics I
INSTRUCTION: Answer Two Questions **TIME:** 2 hrs

You may assume the following where necessary

Plank's constant h	=	6.63×10^{-34} Js
ħ	=	1.05×10^{-34} Js
Electronic mass m_e	=	9.1×10^{-31} kg
Electronic charge e	=	1.6×10^{-31} kg
Velocity of light c	=	3.0×10^{8} m/s
Nuclear radius constant R_o	=	1.4×10^{-15} m
Coefficient of viscosity of oil η	=	1.8×10^{-5} Nm^{2}s
Rydberg constant R	=	1.097×10^{7} m^{-1}
Permittivity of vacuum ϵ_o	=	8.85×10^{-12} Fm^{-1}

QUESTION 1

a. Define the following terms as they apply to photoelectric process:
   i. Threshold frequency ii. Threshold wavelength
   iii Photoelectric work function iv. Stopping potential

b. i. Photoelectric threshold wavelength of a typical tungsten is 230 nm. Assuming that the surface of this material is irradiated by an ultraviolet light of wavelength 180 nm. Calculate the energy of the photoelectrons ejected.

   ii. State the de-broglie's hypothesis. Highlight its importance in duality principle of matter waves.

c. What is pair production? Show that the minimum energy requirement of the process is 1.02 MeV. Determine the corresponding wavelength.

d. Describe Bohr's theory of hydrogen atom and show that wave number of an electron in hydrogen atom is $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ $L = \frac{n\hbar}{2\pi} = n\hbar$

e. i. From Bohr's postulate, what is the angular momentum of the electron in a hydrogen atom when it is in its ground state.

   ii. The energy levels in the hydrogen atom are given by $E(eV) = \frac{-13.6eV}{n^2}$

Calculate the ionization potential and the wavelength of the least energetic photon in the Balmer series.

QUESTION 2

a. Describe Millikan's oil drop experiment and state its relevance to modern science development.

b. From Millikan's drop experiment, the plates are separated by a distance of 150 mm and the oil has a radius of 0.276nm and was made to pass through a distance of 1 cm.

The potential difference applied between the plates is about 0.32×10^4 V. Assuming that the successive time of rise and fall of the oil is 12 s and 78 s respectively. Determine:

i. The change in charge on the oil drop for the two sets of observations

ii. How many electrons does the value you obtained correspond to?

c. i. State the principal results only of the Rutherford's alpha scattering experiment.

ii. A 10 MeV alpha particles are deflected back along the same path when they entered the field of aluminum nuclei ($Z = 13$). Estimate the mass number of the aluminum nuclei. How realistic is this method?

d. What is reduced mass? State its relevance to spectral analysis for mixture of isotopes.

i. According to Sommerfield, $1 - e^2 = \frac{n_2^2}{n_1}$, state the meaning of each symbol.

ii. Show what happens when the Sommerfield ellipse becomes Bohr's circle.

e. Describe x-ray diffraction process and state its importance. Given that a high energy x-rays are made to incident on ZnS crystal. If the first order reflection is observed at Bragg angle of 3.4°. Determine the angle where the second reflection will be observed.

QUESTION 3

a. With good diagram briefly describe how an x-ray is produced. Why are they referred to as characteristic x-rays?

b. Describe briefly the role played by the following parameters on the quality x-rays produced:

i. Filament current ii. Tube voltage

c. i. Define half value layer (HVL). Show that $\frac{I_n}{I} = 2^n$, symbols have their usual meanings. It is desired to reduce a beam of x-rays to $\frac{1}{16^{th}}$ of its initial intensity. The x-rays have a mean energy of 1 MeV and lead will be used as the shielding materials. How many half-value layers are required?

ii Explain why x-ray production is a direct opposite of photoelectric effect.

d. What is a wave packet? Define both group velocity and phase velocity. Show that they are equal in a non-dispersive medium.

e. State the Heisenberg's uncertainty principle. An alpha particle can be considered to be an entity whose uncertainty in its position before emission is equal to the radius of the nucleus of 2.0×10^{-14} m. Assuming that the mass of the α - particle is 6.4×10^{-27}kg, what is its kinetic energy (in eV) just before emission?