

**Instructions to candidates**

Duration: Two (02) hours

Number of questions: Four (04) Essays

Mark allocation: 125 marks

Answer all questions.

$$\text{Plank Constant } h = 6.63 \times 10^{-34} \text{ J.s}$$

$$\text{Mass of a proton} = 1.67 \times 10^{-27} \text{ kg}$$

$$\text{Velocity of light } c = 2.98 \times 10^8 \text{ ms}^{-1}$$

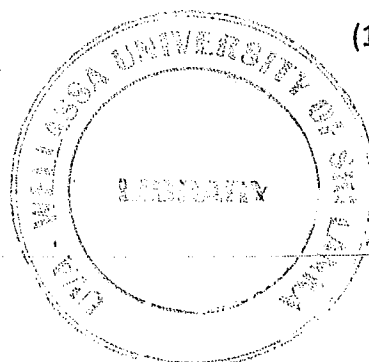
$$\text{Rest energy of a particle of mass } m, E = mc^2$$

$$1 \text{ eV} = 1.6 \times 10^{-19} \text{ C}$$

$$hc = 1240 \text{ eV. nm}$$

$$\hbar c = 197 \text{ eV.nm}$$

- 1.
- a. Briefly explain the “Heisenberg Uncertainty Principle” providing necessary relationships.  
(06 marks)
- b. Briefly describe “The Wave Particle Duality” and give two examples about this phenomina.  
(07 marks)
- c. What is De Broglie’s hypothesis ? Find the De Broglie wavelength of a 5 eV proton.  
Hint : Can use non relativistic kinematics for proton because the energy of the proton is very small compared to its rest energy.  
(10 marks)
- d. A surface of Zinc is illuminated and photoelectrons are observed. Note that the work function of Zinc is 4.31 eV.
- I. What is the largest wavelength that will cause photoelectrons to be emitted?
- II. What is the stopping potential when light of wavelength 220.0 nm is used?  
(12 marks)



2.

- a. Write down four(04) properties of a wave function  $\psi(x)$ , which satisfies the Schrodinger equation.

(08 marks)

- b. The wave function for a quantum system  $\psi(x)$  is given by

$$\psi(x) = Ax^2e^{-3x} \text{ where } A \text{ is an arbitrary constant.}$$

Note that  $\psi(x)$  ranges from 0 to infinity. Find the value of A such that  $\psi(x)$  is a normalized wave function.

Hint :  $\int_0^\infty x^n e^{-ax} = \frac{n!}{a^{n+1}}$  where  $n! = 1 \times 2 \times 3 \times 4 \times 5 \times \dots \times n$

Ex :  $5! = 1 \times 2 \times 3 \times 4 \times 5$

(10 marks)

- c. The wave function of a particle (in its  $n^{\text{th}}$  state) trapped in a one dimensional potential well with length L is given by,

$$\psi_n(x) = \sqrt{\frac{2}{L}} \sin \frac{n\pi x}{L} \quad n = 1, 2, 3, \dots$$

where the symbols have their usual meaning.

Calculate the probability of finding the particle in the first quarter of the potential well ( $L=0$  to  $L=L/4$ ). Assume the particle is in **third** excited state.

Hint :  $\sin^2 x = \frac{1 - \cos 2x}{2}$

(12 marks)

3.

- a. Write an equation for the angular momentum of the Hydrogen atom given by **Bohr model**.

(03 marks)

- b. **Briefly state two** deficiencies (failiures) of the Bohr model.

(06 marks)

- c. State the uncertainty principle related to angular momentum of the hydrogen atom.  
(06 marks)
- d. Find the direction in space where the angular probability density for the  $n=3, l=1, m_l=+1$  electron in hydrogen has its maximum value.

Note that for  $n=3, l=1, m_l=+1$  state the polar function and azimuthal function are given by,

$$\Theta(\theta) = -\frac{\sqrt{3}}{2} \sin \theta \quad \text{and} \quad \Phi(\phi) = \frac{1}{\sqrt{2\pi}} e^{+i\phi}$$

respectively.

(15 marks)

4.

- a. Write down the selection rule which is followed by the hydrogen atom during an atomic transition **in the absence of a magnetic field**.  
(04 marks)
- b. List the excited states (in spectroscopic notation) to which the 4p state can make downward transitions.  
(03 marks)
- c. Briefly explain the term degeneracy of an energy level of a quantum mechanical system.  
(04 marks)
- d. Including the electron spin, what is the degeneracy of the  $n=5$  energy level of hydrogen?  
(04 marks)
- e. Write an equation for the degeneracy of an energy level (considering spin) in terms of principle quantum number  $n$ .  
(03 marks)
- f.
- I. What are the possible values of  $l$  for  $n=6$ ?
  - II. What are the possible values of  $m_l$  for  $l=6$ ?
  - III. What is the smallest possible value of  $n$  for which  $l$  can be 4?
  - IV. What is the smallest possible  $l$  that can have a  $z$  component of angular momentum as  $4\hbar$ ?

(12 marks)

