Uva Wellassa University of Sri Lanka
Faculty of Science and Technology
Department of Science and Technology
300 Level 1st Semester Examination – May/July-2017
SCT 347-2 Quantum Mechanics

Uva Wellassa University

Instructions to candidates
Duration: Two (02) hours
Number of questions: Four (04) Essays
Mark allocation: 125 marks
Answer **all** questions.

Plank Constant h = 6.63×10^{-34} J.s
Mass of a proton = 1.67×10^{-27} kg
Velocity of light c = 2.98×10^{8} ms^{-1}
Rest energy of a particle of mass m, $E = mc^2$
1 eV = 1.6×10^{-19} C
hc = 1240 eV. nm
$\hbar c$ = 197 eV.nm

1.

a. Briefly explain the "Heisenberg Uncertainty Principle" providing nessessary 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)

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2.

a. Write down four(04) properties of a wave function ψ(x), which satisfies the Schrodinger equation.

(08 marks)

b. The wave function for a quantum system ψ (x) is given by

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

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

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

Ex : 5 ! = 1 x 2 x 3 x 4 x 5

(10 marks)

c. The wave function of a particle (in its n[th] state) trapped in a one dimentional potential well with length L is given by,

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

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

(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 hydrogon 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 explian 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 quatum 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 4ħ?

(12 marks)