PYL101

(Electromagnetic Waves and **Quantum Mechanics**)

Tutorial Sheet 2 (L3-L4)

Note: The following are a mixed set of short and descriptive type questions.

1. What is required to describe completely a classical and a quantum particle? If a wave function has to describe the dual nature of quantum particles, what can be its form?

2. Write down Schrodinger's equation for a free particle of mass *m*. How do you describe the state of the particle which is evolving in time?

3. Wave function $\psi(x) = \frac{A}{\sqrt{a}} sin\left(\frac{\pi x}{a}\right) + \sqrt{\frac{3}{5a}} sin\left(\frac{3\pi x}{a}\right) + \sqrt{\frac{1}{5a}} sin\left(\frac{5\pi x}{a}\right)$ describes one state of a particle in one-dimension at initial time t = 0. Find the value of 'A' such that the wave function is normalized.

4. In the above problem, calculate the probability density.

5. Consider a one-dimensional particle which is confined within the region ($0 \le x \le 4$) nm and whose wave function is given by $\psi(x,t) = sin\left(\frac{\pi x}{4}\right) e^{-i\omega t}$. Find the potential V(x) in which the particle is moving.

6. In the above problem, calculate the probability of finding the particle in the region ($1 \le x \le 3$) nm.

7. Apply Heisenberg's uncertainty principle to derive the average size (Bohr's radius) and energy of the ground state of hydrogen atom.

8. What is the de Broglie wavelength of the electron in the ground state of the hydrogen atom?

9. Compare the de Broglie wavelength of electron in ground and first excited states of hydrogen atom.

10. For two non-interacting particles having masses m and 4m both inside a harmonic potential well in one-dimension, draw the energy level diagram in a single graph and mark the positions of their energy levels.

11. Describe 'stationary states' of a quantum system through one example. You should think your own example independently.

12. The eigen functions of a one dimensional harmonic oscillator were shown in the class. Consider the system making a transition from precisely n = 2 state to n = 3 state. Calculate the change in the probability density and the probability current density. Justify the process so that there is no violation of the continuity equation of probability in quantum mechanics.

13. Why is the need for wave packet description of a free particle? Construct a mathematical wave packet representation for a free particle moving in one-dimension and explain.