Module 3

INTRODUCTORY QUANTUM MECHANICS

(As per Revised Curriculum SVU R-2023)

1. Give an account of experimental findings that led de 'Broglie to speculate for wave nature of matter.
2. State and explain de 'Broglie's hypothesis.
3. Derive de 'Broglie's expressions for wavelength of matter in terms of its (i) kinetic energy and (ii) accelerating potential (for a charged matter).
4. State uncertainty principle. Give some of its implications.
5. Arrive at uncertainty product using single slit diffraction of electrons.
6. Arrive at uncertainty product using a thought experiment of seeing an electron by a gamma-ray microscope.
7. What are matter waves? State properties of matter waves.
8. State differences between electromagnetic waves and matter waves.
9. Set up one-dimensional time dependent Schrodinger equation.
10. Starting from Schrodinger's time dependent equation, arrive at time-independent form.
11. Obtain an expression for the wave function of a particle trapped in one-dimensional infinite potential well (particle in a box).
12. The wave function of a particle trapped in one-dimensional infinite potential well is given by $\varphi(x) = A \sin kx$. Determine the constant A using normalization condition.
13. Show that the energy and momentum of a particle trapped in one-dimensional infinite potential well is quantized.
14. Show that the minimum energy of a particle trapped in one-dimensional infinite potential well is not zero.
15. What is the concept of a Quantum computer? What are its advantages?
16. What is qubit? How it is different from conventional bit of classical computers? Which microscopic properties can possibly be used as qubits?
17. State differences between a classical and a Quantum computer.
18. What are Quantum logic gates and quantum circuits? Draw a quantum circuit that produces a superposed state of qubits.

- Try some thought-provoking:

1. Show that we can arrive at Bohr's second postulate by using de 'Broglie hypothesis. Hence estimate de 'Broglie wavelength of an electron in the 1^{st} Bohr orbit (a_0 = 0.5 Å).
2. Explain why wave nature of matter is not observed at the macroscopic level with some examples and arguments.
3. What is wave-particle duality? Can both be observed simultaneously and why?
4. Explain how uncertainty in determination of exact values of physical quantities is related with the wave-particle duality.
5. Show that electron cannot pre-exist in the nucleus by using uncertainty principle. (You need to use relativistic expression for kinetic energy: $K = \sqrt{(m_0c^2)^2 + (pc)^2} - m_0c^2$).
6. What is wave function? What is its role in Quantum mechanics?
7. Explain why measurements appear to be accurate without uncertainties at the macroscopic level with some examples and arguments.

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