The Copenhagen Interpretation

Interpreting Quantum Mechanics

“I think I can safely say that nobody understands quantum mechanics”

- Richard Feynman (1965)

Why the Copenhagen Interpretation

- Niels Bohr and Werner Heisenberg
- 1925-27
- Copenhagen, Denmark
- Contributions by Max Born, Arnold Sommerfield, Wolfgang Pauli, etc.

What led to the Copenhagen interpretation

- Bohr’s semiclassical model of the atom
- Digression from classical mechanics
- Features of the postulates:
  - An electron cannot occupy any point in space -- it is either in the ground state or the excited state.
  - Electron transitions are unpredictable.
  - The electron itself must “know” its initial and final states during a transition to emit a particular frequency.
- Improvement of Bohr’s model by Sommerfeld, Pauli and spin.
- Schrodinger and Born’s contributions.

What is the Copenhagen interpretation

No single definition

Basic principles:

- Indeterminism
- Born’s statistical interpretation of the wave function
- Bohr’s complementarity
- Bohr’s correspondence principle

Indeterminacy

Quantum mechanics is intrinsically indeterminant.

Suppose you measure the position of a particle and you find it at a point A. Where was the particle just before you measured it?

a) Realist position: The particle was at A
b) Orthodox position: The particle wasn’t anywhere
c) Agnostic position: Refuse to answer

Heisenberg’s uncertainty principle

Born’s statistical interpretation of the wave function

The probability of finding the particle at a position is:

$$\boxed{\int_a^b |\Psi(x,t)|^2\,dx = \left\{\begin{array}{l}\text{probability of finding the particle} \\ \text{between } a \text{ and } b, \text{ at time } t.\end{array}\right\}}$$

Reinforces indeterminacy.

Bohr's complementarity

- Wave-particle duality: two sides of a coin

- Kinematic and dynamic properties of the atom:

  Space-time descriptions and claims of causality

Bohr’s correspondence principle

- Transition between stationary states is allowed if and only if there is a corresponding harmonic component in the classical motion.
- The prediction of values in any atomic theory in the domain of high quantum numbers should be a close approximation to the values in classical physics.
- Importance of classical concepts in quantum phenomena.
- Experimental setup and the Heisenberg cut.

Acceptance and criticism

- Most widely accepted
- Polls in 1997 and 2011
- Einstein’s critiques::
  - Epistemic vs ontic
  - Incompleteness and indeterminacy
  - Hidden variables
  - EPR paradox
- “Shifty-split”

References:

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4. https://philnotesblog.wordpress.com/2017/08/29/the-copenhagen-interpretation-of-quantum-mechanics/
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