"JOURNEY OF THE HEISENBERG UNCERTAINTY PRINCIPLE"

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This talk explores the intellectual and philosophical journey behind the Heisenberg Uncertainty Principle, one of the deepest insights of modern physics. In the 1920s, Werner Heisenberg and Niels Bohr confronted a crisis: classical ideas of precise position and momentum could no longer describe the atomic world. Through intense discussions—sometimes lasting late into the night—Bohr and Heisenberg realized that nature itself sets limits on what can be known simultaneously. Heisenberg showed that position and momentum are not independent properties waiting to be measured; they are linked in such a way that increasing the precision of one necessarily blurs the other. This is not due to faulty instruments, but arises from the wave-like structure of matter itself. The uncertainty principle,

$\Delta x \, \Delta p \geq \hbar/2$

expresses a fundamental limit on how reality is organized.

Beyond its mathematical form, the principle forced a radical shift in our view of the universe. Instead of a clockwork world with perfectly predictable motion, quantum physics reveals a realm governed by probabilities, tendencies, and potentialities. This led Bohr to propose *complementarity*—that different experimental arrangements reveal different, mutually exclusive aspects of reality. The talk will then move beyond the technical principle to its deeper implications. If nature itself is not fully determined, what does this mean for causality, predictability, and even free will? Does quantum uncertainty open a space for genuine choice, or is it merely randomness?

By tracing Heisenberg's journey—from mathematical discovery to philosophical debate—this talk shows how a principle about position and momentum ultimately challenges our understanding of knowledge, reality, and human freedom.