

Heisenberg's Uncertainty Principle

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Abstract

Heisenberg's uncertainty principle is usually taken to express a limitation of operational possibilities imposed by quantum mechanics. Here we demonstrate that the full content of this principle also includes its positive role as a condition ensuring that mutually exclusive experimental options can be reconciled if an appropriate trade-off is accepted. The uncertainty principle is shown to appear in three manifestations, in the form of uncertainty relations: for the widths of the position and momentum distributions in any quantum state; for the inaccuracies of any joint measurement of these quantities; and for the inaccuracy of a measurement of one of the quantities and the ensuing disturbance in the distribution of the other quantity. Whilst conceptually distinct, these three kinds of uncertainty relations are shown to be closely related formally. Finally, we survey models and experimental implementations of joint measurements of position and momentum and comment briefly on the status of experimental tests of the uncertainty principle.

Keywords: uncertainty principle, uncertainty relations, approximate measurements, joint measurements, inaccuracy, unsharpness, disturbance

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