

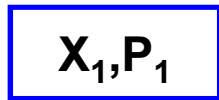
Why operators?

First examples of operators used for a classical state.

With operators you can for example:

1. Describe how physical property can be calculated, give a certain state for the system.
2. Describe how a state B of a system evolves from a state A.

Notation for the state of a particle with mass m , moving in 1 dimension (here a classical state with precise values for X and P):



X_1, P_1




This blue box means “in de state” with the particle at position X_1 and momentum P_1 .

Describe how the final state of a system evolves from an initial state with an operator for time evolution.

Define an operator for time evolution of a state

(here for the case of a free particle):

$$\hat{U}(t_{START}, t_{END})$$


Hat on the U shows that it is an operator.

The result of this operator working on a state X_1, P_1 is

$$\hat{U}(t_{START}, t_{END}) \boxed{X_1, P_1} = \boxed{\left(X_1 + \frac{P_1}{m} \cdot (t_{END} - t_{START}) \right), P_1}$$

Describe how a physical property can be calculated, given a system in a certain state. The example here is for kinetic energy.

Define an operator for kinetic energy:

\hat{T}



Hat on the T shows that it is an operator.

The result of this operator working on the state $\boxed{X_1, P_1}$ is

$$\hat{T} \boxed{X_1, P_1} = \frac{P_1^2}{2m}$$

However, in quantum mechanics a system can be in multiple classical states at the same time. For example, this state:

$$c_a \boxed{X_1, P_1} + c_b \boxed{X_2, P_2}$$

“+” means here “and simultaneously also in this state”

c_a gives the weight for being in that state.

This state is then also possible!

$$c_a \boxed{X_1, P_1} + c_b \boxed{X_2, P_2} + c_c \boxed{X_1, P_2}$$

What is now an easy approach for describe the value(s) for kinetic energy?

$$\hat{T} \left(c_a \boxed{X_1, P_1} + c_b \boxed{X_2, P_2} + c_c \boxed{X_1, P_2} \right) = c_a \frac{P_1^2}{2m} + c_b \frac{P_2^2}{2m} + c_c \frac{P_2^2}{2m}$$

N.B., the pure state $\boxed{X_1, P_1}$ is quantum mechanically not allowed by the Heisenberg uncertainty relation. This is neglected for these examples on operators for classical states.