

The momentum operator in the x-basis

$$\hat{T}(\delta x)|\psi\rangle \rightarrow \boxed{\hat{p}_x \xrightarrow{\text{x-basis}} \frac{\hbar}{i} \frac{\partial}{\partial x}}$$

$$\rightarrow \langle x | \hat{p}_x | \psi \rangle = \frac{\hbar}{i} \frac{\partial \psi}{\partial x} \quad (A)$$

Momentum eigenstates $\hat{p}_x |p\rangle = p |p\rangle$

$$(A) \rightarrow \boxed{\psi_p(x) = \langle x | p \rangle = \frac{1}{\sqrt{2\pi\hbar}} e^{ipx/\hbar}}$$

$$\rightarrow \boxed{\lambda = \frac{h}{p} \text{ or } p = \hbar k}$$

De Broglie relation

In a momentum eigenstate, the position is completely delocalized.