

Quantum Mechanics

Practice Problems on Operators

Problem-1

If \hat{A} is the complex conjugation operator [i.e., $\hat{A}f(x) = f^*(x)$] and $\hat{B}f(x) = \frac{df}{dx}$ for any $f(x)$, show that $[\hat{A}, \hat{B}] = 0$

Solution

$$\hat{A} \hat{B} f(x) = \hat{A} \frac{df(x)}{dx} = \frac{df^*(x)}{dx};$$

$$\hat{B} \hat{A} f(x) = \hat{B} f^*(x) = \frac{df^*(x)}{dx}$$

$$\therefore \hat{A} \hat{B} f(x) - \hat{B} \hat{A} f(x) = 0$$

or

$$(\hat{A} \hat{B} - \hat{B} \hat{A}) f(x) = 0$$

Since $f(x)$ is arbitrary, $\hat{A} \hat{B} - \hat{B} \hat{A} = 0$ or $[\hat{A}, \hat{B}] = 0$

or \hat{A} and \hat{B} commute with each other. ■

Problem-2

Show that $[\hat{x}, \hat{p}_x] = i\hbar$

Solution

For any configuration space wave function $\psi(x)$,

$$[\hat{x}, \hat{p}_x] \psi(x) = \hat{x} \hat{p}_x \psi(x) - \hat{p}_x \hat{x} \psi(x)$$

$$= x \frac{\hbar}{i} \frac{\partial \psi}{\partial x} - \frac{\hbar}{i} \frac{\partial}{\partial x} (x\psi)$$

$$= \frac{\hbar}{i} \left(x \frac{\partial \psi}{\partial x} - \psi - x \frac{\partial \psi}{\partial x} \right)$$

$$= i\hbar \psi$$

Since ψ is arbitrary, $[\hat{x}, \hat{p}_x] = i\hbar$ ■

Problem-3

Show that $[\hat{p}_j, \hat{f}(\vec{r})] = \frac{\hbar}{i} \frac{\partial f}{\partial r_j}$ for $j = 1, 2, 3$

Mechanics Problems And Solutions

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