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Having this

$$\hat{P}_H(t) = \hat{P}\cos(wt) - mw\hat{X}\sin(wt)$$

We can conclude

$$\langle n|\hat{P}_H(t)\hat{P}|n\rangle = \langle n|\hat{P}^2|n\rangle cos\omega t - m\omega\langle n|\hat{X}\hat{P}|n\rangle sin\omega t$$

Knowing that

$$\langle n|\hat{X}\hat{P}|n\rangle = \frac{i\hbar}{2}\ , \langle n|\hat{P}^2|n\rangle = \frac{m\omega\hbar}{2}(2n+1)$$

We get

$$\langle n|\hat{P}_H(t)\hat{P}|n\rangle = \frac{m\omega\hbar}{2}(2n+1)cos\omega t - m\omega\frac{i\hbar}{2}sin\omega t$$

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Translated by: