Quantum Quiz 2

Name:
Number:

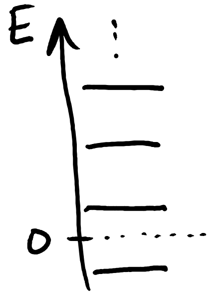
Let $|n\rangle$ be the states of a harmonic oscillator with mass m and frequency ω, and let a and $a^\dagger$ be the usual creation and annihilation operators.

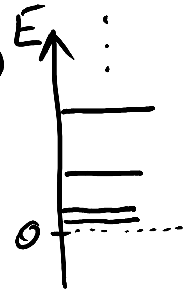
① Which of the following is nonzero?

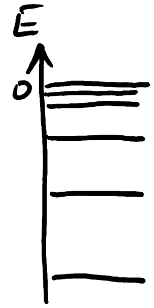
a) $\langle 0|a|0\rangle$ b) $\langle 0|a^\dagger|0\rangle$ c) $\langle 0|a^\dagger a|0\rangle$

d) $\langle 0|a a^\dagger|0\rangle$ e) $\langle 0|x|0\rangle$

② Which diagram best represents the energy levels of a harmonic oscillator?

a)


b)


c)


d)


③ If we add a perturbation λx^6 to the harmonic oscillator Hamiltonian, which of the following gives the shift in the energy of the ground state to first order in λ?

a) $\langle 0|\lambda x^6|1\rangle$ b) $\langle 1|\lambda x^6|0\rangle$

c) $\langle 0|\lambda x^6|0\rangle$ d $\langle 1|\lambda x^6|1\rangle$

e) None of these.

ANSWERS:

#1	#2	#3	#4	#5	#6

④ If we add a perturbation $\lambda(a^2 + a^{\dagger 2})$ to the harmonic oscillator Hamiltonian, the first excited state $|1\rangle$ will shift to

a) $|1\rangle + \lambda \cdot c \cdot |2\rangle + \ldots$

b) $|1\rangle + \lambda \cdot c \cdot |3\rangle + \ldots$

c) $|1\rangle + \lambda \cdot c_1 \cdot |3\rangle + \lambda \cdot c_2 |-1\rangle + \ldots$

d) $|1\rangle + \lambda c_1 |2\rangle + \lambda c_2 |3\rangle + \ldots$

Here, c's are nonzero constants, dots represent λ^2, λ^3, etc...

⑤ The formula $\sum_{m \neq n} \frac{|\langle \psi_m^0 | H_1 | \psi_n^0 \rangle|^2}{E_n^0 - E_m^0}$ represents:

a) The second order correction to the energy of a state $|\psi_n^0\rangle$.

b) The first order correction to the state vector for $|\psi_n^0\rangle$.

c) The first order energy shift in degenerate perturbation theory.

d) The expectation value of operator H_1 at second order in perturbation theory.

⑥ Degenerate perturbation theory is necessary when:

a) we want to find the energy shifts for a group of states whose energies are all the same before adding some perturbation.

b) we want to find the energy shift for <u>any</u> state in a quantum system in which some of the states have the same energy.