Homework #8
(due Wednesday, November 29, 2017)

1. (10 pts) Consider 1D harmonic oscillator. Using the number representation, find the expectation value of $X^4$ in an arbitrary state $|n>$.

2. (10 pts) Sakurai 2.18.

3. (10 pts) Consider 1D harmonic oscillator. Evaluate the following commutators:
   (a) $[P_H(t_1), P_H(t_2)]$
   (b) $[X_H(t_1), X_H(t_2)]$
   Explain the physical meaning of your results.

4. (20 pts) Consider a particle which behaves as 1D harmonic oscillator. Now imagine that your particle is also charged (has an electric charge $q$) and apply uniform electric field $E$ along $x$-axis.
   (a) Find the allowed energy levels and corresponding eigenfunctions. **Hint: you don’t need to solve anything to be able to do it! Add the appropriate term in the Hamiltonian and see how you can reduce the problem to that of a regular harmonic oscillator we discussed.**
   (b) At $t < 0$ the particle is in the ground state. At $t = 0$ the electric field is suddenly turned off. What is the probability to find the particle in the ground state and in the first excited state?

5. (10 pts) A proton of energy $E$ is incident from the right on a nucleus of charge $Ze$. Use the WKB approximation to estimate the transmission coefficient associated with the penetration of the proton inside the nucleus.

6. Reading assignment: Sakurai 2.4-2.6; papers regarding coherent states