Your homework grade includes an explicit 10% that reflects your ability to communicate the work well, including an interpretative statement about your result/mathematics.

1. Use the "bound states" PhET linked on the class page or Mathematica (there are templates) or other package to explore the time-dependent probability density of a particle in in a superposition state of a harmonic oscillator potential.
   (a) Describe the probability density evolution if the particle is in a two-state equal superposition of even states. In particular mention the expectation values of position and momentum (no calculation needed; observe the patterns). Selected screen-shots or graphs will help illustrate.
   (b) Same as (a) but for odd states.
   (c) Explore some other variation that is interesting and discuss.

2. Now for formal calculation: A charged particle subject to a 1-d harmonic oscillator potential is initially in a state $|\psi(0)\rangle$ that is an equal superposition of two (arbitrary) energy eigenstates (but the coefficients are not necessarily real, so there could be a relative phase shift).
   (a) Write down the state $|\psi(t)\rangle$.
   (b) Find the expectation value of the electric dipole moment operator qx , where q is the charge and x is the position operator.
   (c) Interpret your result (notice that part of the exercise is to decide what the interesting choices are; Q1 should help).
   (d) If you make a measurement of the energy of the particle at $t = 0$, what will the outcome be?
   (e) Does the answer to (d) change if $t \neq 0$? If so, how?

3. **Look up the articles** *Nature* **464**, 697-703 (1 April 2010) | doi:10.1038/nature08967 and *Nature* **475**, 359–363 (21 July 2011) | doi:10.1038/nature10261.
   (a) What are the titles & who are the authors?
   (b) Write 100-200 words about how macroscopic quantum oscillators are becoming observable by experimentalists.

4. **McIntyre 10.1** (diagonalize matrix)

5. **McIntyre 10.10** (x^3 perturbation to HO)
   (We may not yet have discussed the second order energy shifts – part b - by the time this homework is due, but it will be really helpful to your understanding if you try to work through the result even if you don't completely understand how you got there. The calculations are really just exercises in using the ladder operators. Usually, having a specific problem to work on helps motivate the discussion).

You should practice problems like 9.16 and 9.17 and similar ones in the text book. They are all about calculating different properties in superposition states.