Problem Set 8
Phy 211 - Fall 2003
Assigned: Friday, Nov. 7; Due: Thursday Nov. 13

Problem 1: $\hat{x}, \hat{p}$ Expectation Values in Simple Harmonic Oscillator Eigenstates

Shankar, Problem 7.4.2

Problem 2: Virial Theorem for Simple Harmonic Oscillator

Shankar, Problem 7.4.3

Problem 3: Time Evolution and the Simple Harmonic Oscillator

Shankar, Problem 7.4.5

Problem 4: Coherent States

Coherent states are eigenstates of the lowering operator

$$\hat{a}|z\rangle = z|z\rangle$$

where z is a **complex** number

First do Shankar,7.4.6. Then use this result calculate $\langle x(t)\rangle$ and $\langle p(t)\rangle$ for a coherent state. Note that, unlike the energy eigenstates, these expectation values evolve like $x(t)$ and $p(t)$ of a classical particle.

Problem 5: More on Coherent States (Graduate Student Problem)

a) Show that

$$|z\rangle = \exp(-|z|^2/2 - z\hat{a}^\dagger)|0\rangle\,,$$

is a normalized coherent state, i.e. $\langle z|z\rangle = 1$. (Hint: the identity $e^A e^B = e^B e^A e^{[A,B]}$ is useful for this exercise.) What is $\langle z'|z\rangle$ for $z' \neq z$? Do coherent states $|z\rangle$ form an orthonormal basis?

b) Find the wave function, $\psi_z(x) \equiv \langle x|z\rangle$, for a coherent state.