

**HAND IN BEFORE THE MIDTERM****LATE HOMEWORK INCURS -10%/WEEKDAY LATE, UP TO 50% MAXIMUM**

You must staple all of your sheets together. All handwritten work must be neatly written.

**1 Griffiths Problem 6.22****2 Griffiths Problem 6.24****3 Non-commuting observables**

A system is in an eigenstate of the angular momentum operators  $L^2$  and  $L_z$ , with corresponding eigenvalues  $\ell, m$ . Calculate the expectation values of  $L_x$  and  $L_x^2$ . expectation of  $L_y$

**4 SHO and Perturbations**

Last week you added a cubic term to the 1D SHO. This week, add a quadratic term

$$H' = bx^2$$

potential to the one-dimensional Simple Harmonic Oscillator.

(a) What is the zeroth order energy:  $E_n^0$ ?

(b) What is the first order perturbed energy:  $E_n^1$ ?

(c) What is the second order perturbed energy:  $E_n^2$ ?

Hint: write the perturbation in terms of  $a_+, a_-$  only.

**5 Stark Effect**

If spin effects are neglected, the four states of the hydrogen atom with  $n = 2$  are completely degenerate with energy  $E_o$ . Show that if you apply a DC electric field  $\mathcal{E}$ , the effect is to only partially break the degeneracy into 3 distinct energies:

$$E_o \pm 3a_o e\mathcal{E},$$

where  $a_o$  is the Bohr radius and  $e$  is the electric charge.