Final Problem Set

Rules: Answer 3 or 4 of the questions below. Your score will be the highest sum of 3 of your answers. You may consult the lecture notes, your homework sets and the solutions. Also, you may consult the Sakurai, Rybicky & Lightman, and Shu texts. You may not consult one another. Due Wednesday, Dec. 10 at 3pm.

(1) Quantum Practice (a.k.a. Sakurai 2.16) [15 pts]
Consider a one-dimensional spherical harmonic oscillator. Do the following algebraically, i.e. without using wave functions.

(a) Construct a linear combination of $|0>$ and $|1>$ such that $< x >$ is as large as possible.

(b) Suppose the oscillator is in the state constructed in (a) at $t = 0$. What is the state vector for $t > 0$ in the Schroedinger picture? Evaluate the expectation value $< x >$ as a function of time for $t > 0$.

(c) Evaluate $< (\Delta x)^2 >$ as a function of time.

(2) Atomic Structure [15 pts]

(a) A He^+ atom has been excited to the 4p state. What are the allowed transitions for electric dipole transitions? Explain, do not just list.

(b) Write down an expression for the lifetime of this excited state.

(c) Draw an energy level diagram describing all of the energy levels for an O^+ ion (i.e. OII) with one electron excited to the 3s level.

(3) Radiative transitions [15 pts]
Discuss the physical principles and assumptions involved in deriving the expression for the spontaneous emission coefficient in semi-classical theory. [Your answer should not be limited to only a couple of sentences. Equations are helpful and encouraged.]

$$A_{fi} = \frac{2}{3}\alpha \frac{\hbar\omega_{fi}}{mc^2}\omega_{fi} f_{fi} \tag{1}$$

(4) Molecules [15 pts]

(a) Explain the Born-Oppenheimer Approximation and its implications for the molecule

(b) Estimate the wavelengths for the electronic, vibrational, and rotational energies of CO.