Astronomy 501 Spring 2013
Problem Set #8

Due in class: Friday, March 29

Total points: 7+0.5

1. [**1 point**] Rybicki & Lightman Problem 8.2.

2. [**1 point**] Rybicki & Lightman Problem 8.3.

3. [**2 points**] Rybicki & Lightman Problem 9.1; each part is worth 0.5 points.

4. [**2 points**] Rybicki & Lightman Problem 9.2; each part is worth 0.5 points.

5. *A Cubic Atom.* An embarassingly crude model of atoms is as follows. Consider an electron in a "square-well potential" in the form of 3-D cubic box, with side length L: the potential is zero inside the box, and infinite outside of it.

   (a) [**0.5 points**] Solve the 3-D Schrödinger's equation to find the electron's eigenstates for this potential, and use this to solve for the energies. You should find that there are three quantum numbers that describe the states, as befits a 3-D system. *Hint:* the result will bear a strong family resemblance to the 1-D "particle-in-a-box" eigenstates familiar from elementary quantum mechanics.

   Estimate a typcical atomic size, and call this L. Find the corresponding "cubic atom" ground-state energy, in eV. How does this compare to the binding energy of hydrogen?

   (b) [**0.5 points**] Find and sketch the 40 lowest energy states and their occupancy, remembering that the Pauli principle holds. Do you find any shell structure? If so, at what numbers of electrons are there shell closings?

   How do these results compare to the electronic structure of real atoms? How do they compare to the *substructure* of levels with the same principal quantum number?

   (c) [**0.5 bonus points**] Consider the cubic atom first excited states with quantum numbers in all permutations of (2,1,1). Sketch the electron probability density for each of these three states. Compare this with the three hydrogen states with $n = 2$, $\ell = 1$, and comment.