Coursework 1 - Atom-Photon Physics Deadline: 17th of November 2012

- 1. (20/100) Explain stimulated emission and spontaneous emission. In your answers, emphasize the differences and similarities between both processes and address the following issues:
 - (a) Which of these processes can only occur in the presence of a radiation field?
 - (b) Can one model both processes rigorously in a semiclassical framework?Why or why not?
 - (c) What happens to the direction and polarization of the emitted photons?
- 2. (15/100) Explain the dipole approximation and its range of validity.
- 3. Consider a generic state $|n, l, m\rangle$ of Hydrogen, where n, l and m denote the principal, orbital and magnetic quantum numbers, respectively. Neglect spin-orbit coupling and fine structure effects.
 - (a) (20/100) For which values of m the 1s and 3d states are coupled by the operator $p_z y p_y z$, i.e.,

$$\langle 1, 0, 0 | p_z y - p_y z | 3, 2, m \rangle \neq 0?$$

Compute the matrix element explicitly. Hint: you will need to use

$$L_x = \frac{L_+ + L_-}{2}$$

and remember how this operator acts upon a state $|n,l,m\rangle$ (check 3rd-year quantum mechanics)

- (b) (10/100) Did you expect that?Why or why not?Justify your answer
- 4. Consider the component xy of the electric quadrupole operator coupling the 1s state and a generic $|n, l, m\rangle$ state.
 - (a) (20/100) Show that the transition matrix element is non-vanishing if $\Delta m = \pm 2, \Delta l = \pm 2$. Hints:
 - Expand x, y in terms of spherical harmonics
 - Use the fact that $(Y_1^{\pm 1}(\theta, \phi))^2 \propto Y_2^{\pm 2}(\theta, \phi)$. Show that writing

$$\left(Y_1^{\pm 1}\right)^2 = \frac{3}{8\pi} \left(\sin\theta\right)^2 \exp[\pm i2\phi]$$

(b) (15/100) Write the sublevels coupled by the above-stated electric quadrupole transition from the 1s to the 3d states in terms of the quantum numbers j, m_j associated with the *total* angular momentum operator $\mathbf{J} = \mathbf{L} + \mathbf{S}$.

Hint: They are written in the form nL_j (for instance, $2p_{3/2}$ corresponds to n = 2, l = 1 and j = 3/2)