Coursework 3 - Atom-Photon Physics
Deadline: First day of 2^{nd} term (January 2014)

1. (8/100) Define the ponderomotive energy and explain its physical meaning. Explain also why it is not important for low-intensity laser fields (base your explanation on the atom+light hamiltonian)

2. (12/100) What is the physical meaning of a Volkov state? Is there a particular Hamiltonian connected to it?Why is it useful for the treatment of strong-field phenomena? Provide the explicit expression for a Volkov state $< \mathbf{r}|\mathbf{p} + \mathbf{A}(t) >$ in position representation and discuss what happens in the limit of vanishing external field. Explain what kind of problems arise when approximating the continuum by Volkov states in the strong-field approximation.

3. Address the following issues related to high-order harmonic generation:

   (a) (17/100) What features in the high-order harmonic spectrum contradict the predictions of perturbation theory?Why?Provide an explanation for these features and explain the physical mechanism behind HHG. Provide also schematic representations of a typical HHG spectrum and of what one would expect according to perturbation theory.

   (b) (13/100) Why can high-order harmonics be used in the production of attosecond pulses? Would this be possible according to perturbation theory? Why or why not?

4. (15/100) Explain the laser-beam configuration employed to obtain optical molasses. Thereby, emphasize the importance of the laser-beam directions and frequencies and explain what kind of net force is encountered. Provide a schematic representation. Does this set up confine atoms? Why or why not?

5. (15/100) Provide a schematic representation of a magneto-optical trap. Explain how the laser frequencies and polarizations are used to confine atoms in a potential minimum. Focus on what kind of force is present in this scheme and give and example for a two-level atom with an excited state of j=1 and a ground state of j=0.

6. (20/100) Explain the Sisyphus cooling mechanism in terms of light shifts and polarization gradients. Provide an example of how this mechanism works using two counter-propagating orthogonal linearly polarized waves and an atom whose ground state has j=1/2 ($m_j = \pm 1/2$) and whose excited state has j=3/2 ($m_j = \pm 1/2, \pm 3/2$) . Use the notation $e_{\pm 1/2}, e_{\pm 3/2}$ for the excited Zeeman sublevels, and $g_{\pm 1/2}$ for those related to the ground state. Provide schematic representations of the process, of the resulting

polarizations. For simplicity, neglect the light shifts of the excited state. You will need to use the information provided in Fig. 1.

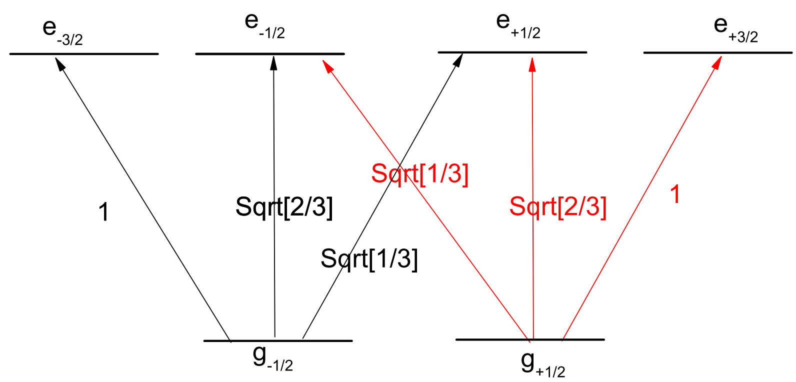

Figure 1: Schematic representation of the ground and excited Zeeman sublevels involved in the specific Sisyphus cooling process given in Question 6. The numbers in the figure give the Clebsch Gordan coefficients.