Coursework 3 - Atom-Photon Physics
Deadline: First day of 2^{nd} term (January 2012)

1. Address the following questions related to above-threshold ionization (ATI):

   (a) (15/100) What does "above-threshold" mean?Why does this phenomenon occur?Formulate your answer in terms of the ponderomotive energy and Stark shifts. Explain why ATI does not happen for weak fields.

   (b) (20/100) What are the typical features encountered in an ATI spectrum?Explain the physical mechanisms behind these features. Thereby, make a clear distinction between "direct" and "rescattered" electrons. What features can be related to the maximal photoelectron energies?

2. **The Volkov solution.** Consider the expression

$$\psi^{(V)}(\mathbf{r},t) = \frac{\exp[i\mathbf{p}\cdot\mathbf{r}]}{(2\pi)^{3/2}} \exp\left[-i\int_{-\infty}^{t} \frac{[\mathbf{p}+\mathbf{A}(\tau)]^2}{2} d\tau\right]. \tag{1}$$

   (a) (10/100) Show that it satisfies the time-dependent Schrödinger equation

$$i\frac{\partial\psi^{(V)}(\mathbf{r},t)}{\partial t} = \frac{[\mathbf{p}+\mathbf{A}(t)]^2}{2}\psi^{(V)}(\mathbf{r},t). \tag{2}$$

   (b) (15/100) Explain, physically, what Eq. (2) represents, together with Eq. (1). Consider now Eq. (2) in the limit of vanishing vector potential, i.e., $\mathbf{A} \to 0$. Physically, what does this mean?Provide a discussion in terms of an electron propagating in the laser field.

   (c) (10/100) Why are Volkov waves useful in the theoretical modeling of strong-field phenomena?

3. Answer the following questions related to laser cooling:

   (a) (15/100) Why can one employ a counter-propagating laser beam to cool atoms? Explain this in terms of momentum transfer from the field to an atom and vice-versa.

   (b) (15/100) What is the Doppler cooling limit and why does it occur?Base your explanation on the momentum and energy transfers over one absorption-spontaneous emission cycle of a photon of momentum $\mathbf{k}$ and an atom of velocity $\mathbf{v}$.