Homework 1: (PHY249 Plasma Accelerator Physics, Fall 2021, Tajima)

Deadline: Oct. 8 Friday, 2021, 5pm to ttajima@uci.edu (cc: to Greg: huxtablg@uci.edu

(Your collaboration among your colleagues is encouraged. If you work together to work out the homework, please show your colleagues' names together in your submission. (If you wish to submit your homework answer collectively together as a group, that is also OK with showing on who are your co-authors. If you have any questions, feel free to ask me).

Homework 1 is about: Derivation of the wakefields by laser. Also the density hump of wakefields as a function of the laser intensity.

As I showed on the white board on the first class (Sept. 23), we discussed about the ponderomotive force.

1. The first step was to derive the ponderomotive force. This is generated in the plasma by the laser pulse in the direction of the laser propagation. Show how to derive the ponderomotive force, as I showed on the board. ($F\_p \sim mc^2\ \omega\_p\ a_0{}^2 / c$). Here a_0 is called the normalized strength parameter $a_0 = e\ E_0\ / m\ \omega\_o\ c$, where E_0 and ω_o are the laser electric field and frequency. Note here that I assumed that the laser pulse length was about c / ω_p, over which the gradient of the ponderomotive potential force the active gradient.

   The ponderomotive force is preferentially larger on electrons than on ions. Why?
2. The second step is to assess the charge separation driven wakefield generation.

This preferential push of electrons by the laser pulse (let us assume its laser pulse length is over the distance c / ω_p, where ω_p is the plasma frequency of the plasma) causes electrons pushed forward, while ions stay where they are. This sets up a charge separation between electrons and ions. This force is the usual electrostatic force, which I also derived on the board. $F = e\ E\_s$, where E_s may be derived by the Gauss' Law. (After quick algebra I showed this goes like $F\_w \sim\ 4\pi\ e\ \delta n\_e\ c/\omega\_p$). . Here n_e is the total electron density of the plasma, while δn_e is the charge-separated electron density.

3. The third step is you equate these two forces.

This F_w is the force to cause the wakefield. If the ponderomotive force is the driver of this charge separation, as I argued, you can equate the ponderomotive force to the charge separation force F_w to show how far the electron charge separation can be generated δn_e. The expression I derived on the white board was:

$$\delta n_e\ / n\_e \sim a_0{}^2$$

Show this (within a factor of 2, 4, or pi is OK).