Assignment 3: Modifying the sheath system to include collisions

David Dickinson d.dickinson@york.ac.uk

Semester 1

This time we're going to modify the assumptions in the Debye sheath model, and start to include some effects which might be present in a real plasma, such as collisions between ions and background gas. To model this, we'll assume a fixed collision-length L over which ion momentum is lost. Rather than using conservation of energy for the ions as before:

$$\frac{1}{2} m_i v_i (x)^2 = \frac{1}{2} m_i v_s (x)^2 - e\phi (x)$$

we will now need to solve an ODE for the ion momentum. Differentiating the above equation gives:

$$m_i v_i \frac{dv_i}{dx} = eE$$

Rearranging, and adding a loss term gives

$$\frac{dv_i}{dx} = \frac{e}{m_i v_i} E - v_i / L$$

where L is the length over which ion momentum is lost by collisions with neutrals.

Tasks: The assignment is split into three tasks, with a total of 10 marks.

Task [5 marks] Normalise the above equation (hint: L should be normalised to λ_D) and add it to the system of equations so that the normalised ion velocity $\hat{v}_i$ is solved along with $\hat{E}$ and $\hat{\phi}$. You may assume $\hat{v}_s = 1.0$. You'll need to provide a starting value for $\hat{v}_i$. Normalise and use solve_ivp to solve for v_i

Task [3 marks] Plot the ion velocity as a function of distance from the wall for different values of L from 0.1 to 10^4 in powers of 10 (i.e. a logarithmic scale) on the same figure. You'll need to use the position $\hat{x}_w$ where $\hat{j}$ goes to zero calculated in assignment 2.

Task [2 marks] Add a plot of the ion velocity at the wall against L on a logarithmic X axis. You'll need to use interpolation again, and you can use the Matplotlib function `xscale('log')` to get a log scale. To set the x and y scale limits, you can use `xlim([min, max])` and `ylim([min, max])`. This can be a separate plot if you prefer rather than showing the plot as an inset (as shown in the example below).

1 Example plots

To help you check your implementation the following figure shows an example result. It should be noted that whilst the figure shows "correct" data the presentation would need to be improved for full marks (so don't just copy this!).

Points to consider: Please pay attention to how you present your figures, part of the marks available are for the quality of the presentation. Code quality influences the marks in this assignment (e.g. see the hint about not using copy-paste/duplication). This also includes ensuring that you provide sufficient comments in the code to explain what you are doing and why.

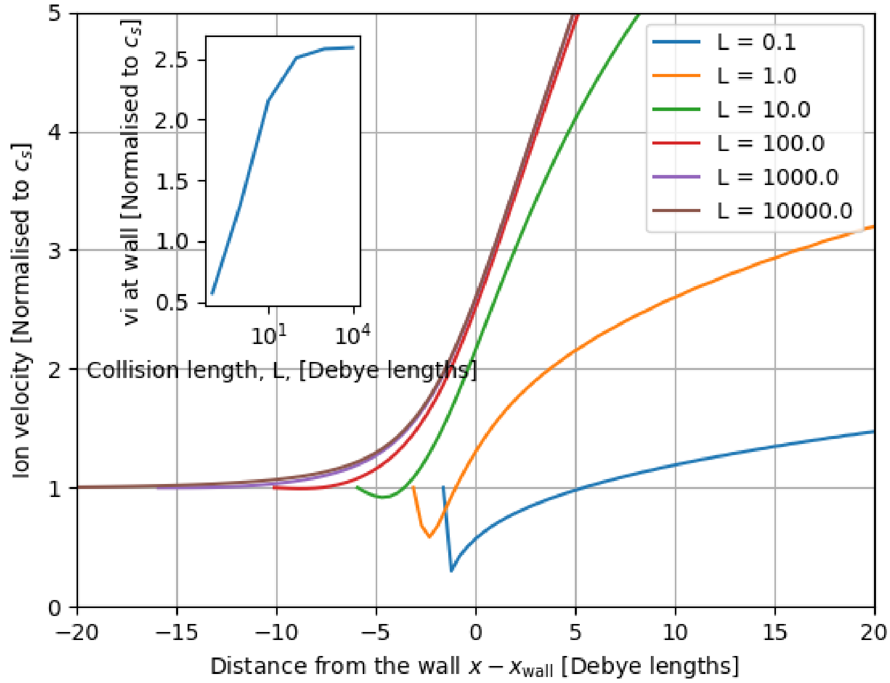

Figure 1: Figure showing plot of normalised ion velocity as a function of the normalised distance from the wall $\bar{x}$ for a range of normalised collision lengths, $\hat{L}$. Instet plot shows the velocity at the wall as a function of $\hat{L}$, showing this increasing as $\hat{L}$ increases.