Plasma I

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Exercise 1

Evaluate the value of the speeds $\sqrt{\langle v_x^2 \rangle}$, $\sqrt{\langle \vec{v}^2 \rangle}$ and $\langle |\vec{v}| \rangle$ as a function of the thermal velocity defined as $v_{th\alpha} = \sqrt{\frac{T_\alpha}{m_\alpha}}$ for a maxwellian distribution:

$$f_\alpha(\vec{v}) = \left(\frac{m_\alpha}{2\pi T_\alpha}\right)^{3/2} \exp\left(-\frac{m_\alpha}{2\,T_\alpha}\vec{v}^2\right)$$

Exercise 2

To produce a plasma, a cylindrical vacuum tube (length $l = 2$m, radius $a = 1$m) is pumped down to a base pressure $p < 10^{-8}$torr (760torr is the atmospheric pressure), and then filled with Argon (ionization energy 15.8 eV) at $p = 10^{-3}$torr that you can assume to be at room temperature. A mono-energetic electron beam (radius $r = 10$cm, total current $I = 1$A and energy $U_e = 30$eV) is injected along the axis of the tube using an electron gun.

a.) Evaluate the total number of ions per second produced in the tube by the impact of the electrons on the neutrals.

b.) Assuming no recombination and no fueling of gas, how long could we maintain this discharge?

Suppose to have an ionisation cross-section for electrons at 30eV of $\sigma_{ion} \sim 10^{-20}\text{m}^2$.

Exercise 3

Semi-conductor manufacturers use plasma during surface treatment of materials. In a vacuum chamber of 0.5m × 0.5m × 0.5m dimensions, an inert gas is partially ionised by radio waves.

Consider the case where the gas used is Argon that you can assume to be at room temperature ($p = 10^{-4}$torr , $n_e = 10^{16}\text{m}^{-3}$, $T_e = 3$eV, and $T_i = 0.1$eV - first ionisation):

a.) Calculate the relative ionisation degree of the gas used.

b.) Estimate the collision frequency (electron-neutral ν_{en}) assuming a cross section of $\sigma = 1000\pi a_0^2$, where $a_0 = 5.29 \times 10^{-11}$m is the Bohr radius.

c.) Can we consider this gas as a plasma? Why?