Plasma II - Exercises

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1 Multi-choice questions

1.1 If the electron flux to an electrode is not equal to the ion flux, this means that:

( ) the electrode is electrically floating.

( ) there will soon be no gas left between the electrodes.

( ) the ions are much heavier than the electrons.

( ) there is an electric current flowing.

1.2 The sheath is a dark layer principally because:

( ) the Force is not with it.

( ) T_e is lower than in the plasma bulk, which reduces the gas excitation rate.

( ) the electrode surface absorbs the light in the vicinity of the sheath.

( ) n_e is lower than in the plasma bulk, which reduces the gas excitation rate.

1.3 The Boltzmann relation can be used to calculate the electron density in the sheath because:

( ) the electron drift velocity is much smaller than the electron thermal velocity.

( ) the ion drift velocity is much smaller than the ion thermal velocity.

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1.4 Negative ions in a plasma can have almost the same mass and temperature as positive ions. Therefore:

( ) They cross the sheath in a similar way to positive ions.

( ) They cross the sheath in a similar way to electrons.

( ) They cross the sheath in a similar way to neutrals.

( ) They cannot cross the sheath and are trapped in the plasma.

Exercise 1 - Electron motion and ohmic power in radio-frequency fields

Consider a uniform plasma in a background gas with a time-varying electric field $\vec{E}(t)$. The first moment of the Boltzmann equation gives the intuitively-reasonable momentum balance for the electrons:

$$m\frac{\partial \vec{u}}{\partial t} = -e\vec{E}(t) - m\nu_{e/n}\vec{u}$$

where $\vec{u}$ is the electron velocity and $\nu_{e/n}$ is the electron-neutral collision frequency.

a) Writing $\vec{E} = \vec{E}_0 \exp(i\omega t)$, find an expression for the electron RF current $\vec{j} = -ne\vec{u}$ and hence find the time-averaged ohmic power P_{ohm} per unit volume.
Hint: the time-averaged power $\langle \vec{j} \cdot \vec{E} \rangle = \frac{1}{2}\Re(\vec{j} \cdot \vec{E}^*)$.

(Note: the power transfer is zero in absence of collisions.)

b) Show that the ohmic power transfer to the plasma, for a given RF frequency, reaches a maximum when the angular RF frequency $\omega = \nu_{e/n}$ as the pressure is varied.

Exercise 2 - Practise the derivation of Bohm's criterion, ion flux, and ion energy to a floating wall

(See Lecture Notes, slides 21-29)

Exercise 3 - Ion energy in RF plasmas

An engineer needs to bombard a substrate with a constant flux 100 eV ions for an etching process. Explain why you recommend to use an RF power generator at 13.56 MHz frequency with a peak-to-peak output voltage of 400 V. Note that at the chosen gas pressure the RF heats electrons to approximately 2 eV.