PHYSICS 180E, WINTER 2025

HOMEWORK 4
(DUE WEDNESDAY FEB. 19 BY MIDNIGHT ON GRADESCOPE)

1. A planar Langmuir probe is made of a tantalum foil and is square with 2 mm sides – assume one face of the foil is insulating. At ion saturation, the probe draws 100 μA from an Argon plasma. If the electron temperature is 2 eV, what is the plasma density? In the same plasma, the floating potential is measured to be +2 V relative to chamber ground. What is the plasma potential?

2. Estimate the mean free path for electrons colliding with neutrals in a plasma with similar parameters to what you will be doing experiments with: neutral gas pressure 1 mTorr, electron density 10^{11} cm^{-3}, electron temperature 5 eV. How does the mean free path compare to the Debye length in this plasma (in other words, do the electrons undergo collisions in the sheath around the Langmuir probe? If so, our theory is not valid!). Recall that the Debye length is:

$$\lambda_D = \sqrt{\frac{\epsilon_0 k_B T_e}{e^2 n}}$$

Hint: you can estimate the cross-section of a neutral atom as the approximate cross-sectional area of the atom. Google it, but roughly 10^{15} cm^2 works.

3. Using data from your first Langmuir lab session, analyze the I-V characteristics of a single Langmuir sweep to calculate the following plasma parameters:

   (a) Electron temperature

   (b) Plasma potential

   (c) Electron density

4. Answer the following questions using the data obtained from your Langmuir sweep analysis above.

   (a) Are your derived measurements for density and temperature reasonable? Does your measured plasma potential make sense? Why or why not? Recall the discussion in lecture over how the plasma potential gets established (by flow of charge from the plasma to the wall and vice versa)

   (b) How does your electron temperature compare to the ionization potential of Argon? Recall we discussed different types of ionization in lecture, including "bulk" ionization (plasma electrons with the temperature you measure colliding with Argon neutrals and ionizing them) and ionization by primary electrons (the electrons accelerated by the discharge voltage). Is your electron temperature large enough that the average electron can ionize Argon? Under what conditions would bulk ionization dominate over primary ionization?

A useful resource for equations in this lab is the Naval Research Laboratory's "Plasma Formulary", a copy of which you can find on the course website.