2006 Part II Q2 Exp.

e^- species 1: $T_1 = 1\,eV$, $n_1 = 10^{18}\,m^{-3}$ e^- species 2: $T_{e2} = 10\,eV$, $n_2 = 10^{18}\,m^{-3}$ $E_3 = 100\,eV$, $n_3 = 10^{15}\,m^{-3}$

A. Debye length $\lambda_D = \sqrt{\frac{\epsilon_0 T_e}{n e^2}}$ $\frac{1}{\lambda_{Dtot}^2} = \frac{1}{\lambda_{D1}^2} + \frac{1}{\lambda_{D2}^2}$

$\lambda_{D1} = 7.4 \cdot 10^{-6}\,m$ $\lambda_{D2} = 2.35 \cdot 10^{-5}\,m$

$\Rightarrow \lambda_D = 7.1 \cdot 10^{-6}\,m$

Probe size $d >> \lambda_D$

Shape: planar, oriented normal to the electron beam. (opposite side insulated)

$\rightarrow$ Don't want a cylindrical or spherical probe, because the plasma itself is anisotropic

B. The floating potential is the potential it reaches when unbiased, so that there is no net current flowing to it

$J_i = J_{e1} + J_{e2} + J_{e3}$

$I_i = I_{is}$, and I will assume I_{is} takes on the form it does for the higher energy Maxwellian: (but with n_H)

$J_{is} = 0.6\, n_H e V_B$, with Bohm velocity $V_B = \sqrt{\frac{T_{e2}}{m_i}}$ $T_{e2} = 10\,eV$

$$\Rightarrow 0.6 n_H V_B = n_1 \sqrt{\frac{T_{e1}}{2\pi m_e}} \exp\left(\frac{e(V_f - V_{sp})}{T_{e1}}\right) + n_2 \sqrt{\frac{T_{e2}}{2\pi m_e}} \exp\left(\frac{e(V_f - V_{sp})}{T_{e2}}\right) + n_3 V_3 H\left(E_3 - e(V_{sp} - V_f)\right)$$

Heaviside step

$n_H = n_1 + n_2 + n_3 \approx n_1 + n_2 \approx 2 \cdot 10^{18}\,m^{-3}$

$$\frac{J_{e3}}{J_i} \approx \frac{n_3 V_3}{0.6\, n_H V_B} = \frac{n_3}{0.6\, n_H} \frac{\sqrt{\frac{2E_3}{m_e}}}{\sqrt{\frac{T_{e2}}{m_i}}} = \sqrt{2}\, 1.7 \frac{n_3}{n_H} \sqrt{\frac{m_i}{m_e}} \sqrt{\frac{E_3}{T_{e2}}} = 7.4 \cdot \frac{n_3}{n_H} \cdot \sqrt{\frac{m_i}{m_e}} = 7.4 \cdot \frac{1}{2000} \cdot \sqrt{1836}$$

$$\frac{J_{e3}}{J_i} \approx .16$$

• current from beam is not enough to neutralize ion current, so these particles will be collected. $\left(E_3 > e(V_{sp} - V) \right)$

$n_H = 2n_1 = 2n_2$, and let $\epsilon = \frac{n_3}{n_1} = \frac{1}{1000}$

$$\Rightarrow 0.6 \cdot 2 \cdot V_B = \sqrt{\frac{T_{e1}}{2\pi m_e}}\, \exp\left[\frac{e(V_f - V_{sp})}{T_{e1}}\right] + \sqrt{\frac{T_{e2}}{2\pi m_e}}\, \exp\left[\frac{e(V_f - V_{sp})}{T_{e2}}\right] + \epsilon V_3$$

Since $T_{e1} << T_{e2}$, first term on RHS will be negligible compared to second, due to exponential factor.

$$\Rightarrow \quad 1.2 V_B - \epsilon V_3 \approx \sqrt{\frac{T_{e2}}{2\pi m_e}}\, \exp\left[\frac{e(V_f - V_{sp})}{T_{e2}}\right]$$

$$\Rightarrow \frac{e(V_f - V_{sp})}{T_{e2}} = \ln\left(\sqrt{\frac{2\pi m_e}{T_{e2}}}\,(1.2 V_B - \epsilon V_3)\right)$$

$$\Rightarrow V_{sp} - V_f = \frac{T_{e2}}{e} \ln\left(\sqrt{\frac{T_{e2}}{2\pi m_e}}\ \frac{1}{1.2 V_B - \epsilon V_3}\right)$$

$V_{sp} - V_f = 10V \times 2.83$

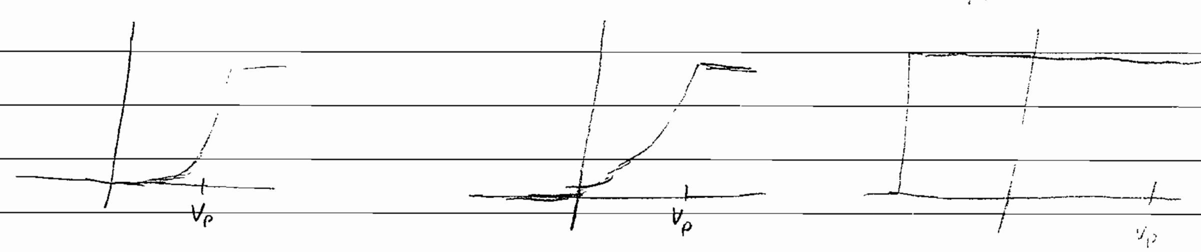
$$V_{sp} - V_f = 28.3\ V$$

Flux of species 1 (1eV) collected: $\exp(-28.3) = 5 \cdot 10^{-13}$

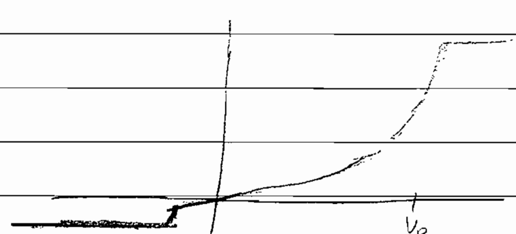
Flux of species 2 (10eV) collected: $\exp(-2.83) \approx 0.06$

Flux of species 3: all of them = 100%

c. Species 1 $\qquad$ species 2 $\qquad$ species 3



net:



$J_{is} = e\,0.6\, n_H V_B \cong 6 \cdot 10^3 \frac{A}{m^2}$ $\qquad$ $J_{es} = \left(n_1 \sqrt{\frac{T_{e1}}{2\pi m_e}} + n_2 \sqrt{\frac{T_{e2}}{2\pi m_e}} + n_3 V_3\right) e = 1.1 \cdot 10^5 \frac{A}{m^2}$

D. Two-fluid theory for probe data

Would capture ion density, ~ temperature of more energetic species (10 eV).
(because that is most of the characteristic)

Would miss the beam, lower temp Maxwellian

But probe analysis is inherently kinetic