I.8 Langmuir Probe [40 pts]

A planar probe is immersed into a collisionless steady-state plasma with Maxwellian electron energy distribution function, cold ions, and $T_e \gg T_i$.

(a) [10 pts] Derive the expression for the floating potential of the probe with respect to the plasma assuming no electron emission from the probe.

(b) [15 pts] Consider the floating probe is heated by plasma to temperatures when it starts to emit electrons. Assume that the temperature of emitted electrons is negligible compared to the temperature of plasma electrons. Derive the expression for the floating potential of the electron emitting probe.

(c) [5 pts] Consider a sweeping bias voltage is applied to the probe. The bias voltage is swept to get the full probe V-I characteristic. Show qualitative changes of the this characteristic induced by the electron emission due to the probe heating - show probe V-I's at different probe temperatures (i.e. different electron emission currents).

(d) [10 pts] Consider a planar Langmuir probe for measurements in a magnetized plasma. How to select the probe diameter to avoid a depletion of electrons density in the magnetic flux tube sampled by a probe?

$$I_{is} = 0.6\, e\, n_i \sqrt{\frac{eT_i}{m_i}}\, A_p$$

$$I_{es} = \frac{1}{\sqrt{2\pi}}\, e\, n_e \sqrt{\frac{eT_e}{m_e}}\, A_p$$

$$I_e(V) = I_{es}\, e^{(V_{probe} - \phi_f)/T_e}$$

at ϕ_f, $\Gamma_i = \Gamma_e$

$$I_{is} = I_e$$

$$0.6\, e\, n_i \sqrt{\frac{eT_i}{m_i}}\, A_p = \frac{1}{\sqrt{2\pi}}\, e\, n_e \sqrt{\frac{eT_e}{m_e}}\, A_p\, e^{(V-\phi_p)/T_e}$$

Quazi newtrality

$$-T_e \ln\left(\frac{1}{0.6\sqrt{2\pi}}\sqrt{\frac{m_e}{m_i}}\right) = \phi_f$$

b)

$$\sum \Gamma = 0$$

$$\Gamma_{pi} - \Gamma_{pe} + \Gamma_{ee} = 0$$

Let $\gamma = \frac{\Gamma_{ee}}{\Gamma_{pe}}$

$$\frac{\Gamma_{pi}}{\Gamma_{pe}} - 1 + \gamma = 0$$

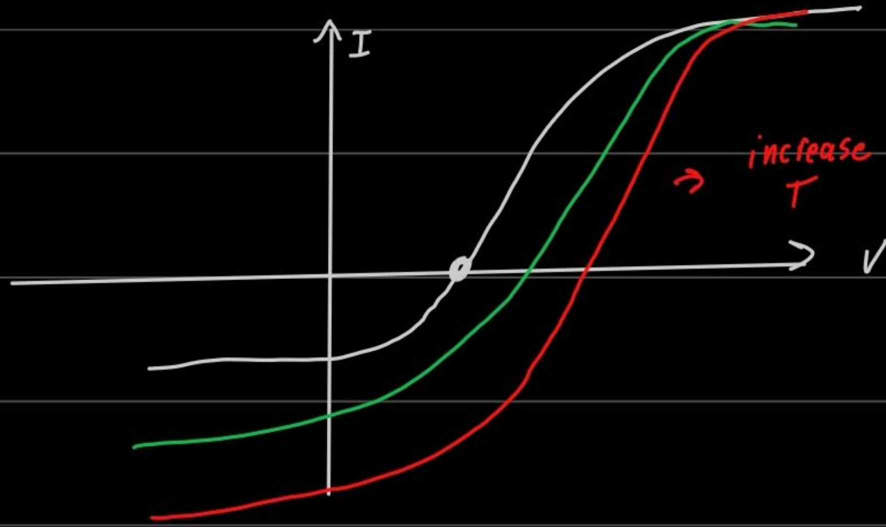
$$\frac{\Gamma_{pi}}{\Gamma_{pe}} = 1 - \gamma$$

$$\Gamma_{pi} \frac{1}{1-\gamma} = \Gamma_{pe}$$

$$0.6\, e\, n_i \sqrt{\frac{eT_i}{m_i}}\, A_p \frac{1}{1-\gamma} = \frac{1}{\sqrt{2\pi}}\, e\, n_e \sqrt{\frac{eT_e}{m_e}}\, A_p\, e^{\phi_f/T_e}$$

$$-T_e \ln\left((1-\gamma)\frac{1}{0.6\sqrt{2\pi}}\sqrt{\frac{m_i}{m_e}}\right) = (V - \phi_p)$$

c)



D) Use a large enough diameter to get enough flux tubes to get more electrons

diameter $<< \rho_{L,e^-}$