2013 II 4A JH

This describes a double probe: there is no ground in space (+ no screening) so the current drawn by one shuttle (probe) is the same as the current emitted by the other probe.

$$I_1 = -I_2$$

Now each probe is biased V_B wrt to the other

$$I_1 = I_{is} - I_{es}\exp\left(\frac{e(V_s - V_f - V_B/2)}{kT_e}\right) \quad \updownarrow \pm$$

$$I_2 = I_{is} - I_{es}\exp\left(\frac{e(V_s - V_f + V_B/2)}{kT_e}\right)$$

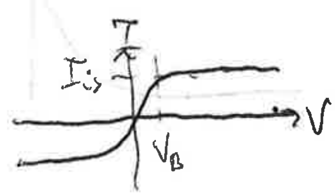
$I_1 = -I_2$ gives $I_{is} = I_{es}\exp\left(\frac{e(V_s - V_f)}{kT_e}\right)\left[\exp\left(\frac{eV_B}{2kT_e}\right) + \exp\left(\frac{-eV_B}{2kT_e}\right)\right]$

$$= I_{es}\exp\left(\frac{e(V_s - V_f)}{kT_e}\right)\cosh\left(\frac{eV_B}{2kT_e}\right)$$

If we measure the currents I_1 and I_2, we find

$$I_1 + I_2 = I_{es}\exp\left(\frac{e(V_s - V_f)}{kT_e}\right)\left[\exp\left(\frac{eV_B}{2kT_e}\right) - \exp\left(\frac{-eV_B}{2kT_e}\right)\right]$$

$$= I_{is}\tanh\left(\frac{eV_B}{2T_e}\right)$$



So, what can we measure?

- T_e from slope near $V_B \sim 0$ $\quad \tanh x \sim x$ for small x.
- Then n_e from $I_{is} = 0.6\, n_e e A c_s$ $\quad$ Oxygen mass $= 16$ amu

($n_e \sim 10^{12}\,m^{-3}$, $A \sim 20\,m^2$)

Use the formulary to find

$$I_{is} \sim 7\,mA$$

(check you can do this w/out a calculator!)

To get to I_{is} region, need to bias the probe so that we are in the asymptote, $\tanh x \xrightarrow{x\to\infty} 1$

$$\tanh x = \frac{e^{x} - e^{-x}}{e^{x} + e^{-x}} \to 1 \text{ if } e^{-x} \ll e^{x}$$

Hence need $\exp\left(-\frac{eV_B}{kT_e}\right) \ll 1$ so V_B should be a few $\frac{kT_e}{e}$ $\sim 20V$ for $T_e \sim 2V$

Power supply must be able to draw $\sim 10\,mA$ and bias $\pm 20V$

b)