2005 Part 1 Q2 Exp.

a. $V_f = -3\,V$

b. $I_e = I_{es}\exp\left(\frac{e(V-V_{sp})}{T_e}\right)$ $\quad I_{es} = \frac{1}{4} n e A \bar{v}$ $\quad \bar{v} = \sqrt{\frac{8T_e}{\pi m_e}}$

$\ln I_e = \ln I_{es} + \frac{eV}{T_e} - \frac{eV_{sp}}{T_e}$

$\Rightarrow \ln I_e = \frac{e}{T_e} V + C$ $\quad$ slope $= \frac{e}{T_e}$

Since $I_{is} = -1$, $\quad I_e(V=-3) = 1$ mA $\quad \ln 1 = 0$

$I_e(V=0) \approx 5.3$ mA $\quad \ln 5.3 = 1.668$

Find the slope: $\frac{e}{T_e} = \frac{1.668 - 0}{0-(-3)\,V} = \frac{1.668}{3V} = 0.56\,\frac{1}{V}$

$\Rightarrow \frac{T_e}{e} = 1.8\,V$, or $T_e \approx 1.8$ eV

c. Ionization potential for Argon ~ 15.8 eV, so the likely charge state is $Z=1$

d. $I_{is} = 0.6\, e A n \sqrt{\frac{T_e}{m_i}}$ ← Bohm velocity $\quad m_i \approx 39.9\, m_p$

$I_{is} = 1$ mA $\quad A = \pi \cdot (1\text{mm})^2 \times 2$ ← factor of 2 because probe is double-sided

$I_{is} = 10^{-3}$ A $\quad A = 2\pi \cdot 10^{-6}\ m^2$

$\Rightarrow n \sim 7.96 \cdot 10^{17}\ m^{-3} = 7.96 \cdot 10^{11}\ cm^{-3}$

e. $I_{es} = \frac{1}{4} n e A \sqrt{\frac{8T_e}{\pi m_e}} = 63.6$ mA $\quad (I_i \to 0$ or $V = V_p)$

$I = 63.6$ mA

f. discontinuity in current; when $-(V-V_{sp})e > 10$ eV, all electrons repelled; otherwise, all collected