J09E.2 - Ion Source

Problem

Consider two infinite parallel plates separated by a distance a and with the gap between the plates filled with charged ions in vacuum. Assume that the motion of the ions is a one-dimensional laminar flow in the direction of the applied electric field. In the space-charge dominated limit, the electric field between the anode and the cathode is maximally shielded by the ion charge. Assume that the ions are initially emitted at the cathode $s = 0$ and travel to the anode at $s = a$ where they leave the plates through small negligible holes in the anode plate. The ion emission at the cathode maintains a static, steady state charge distribution between the plates and therefore a constant current at the anode plate. Let $V(s)$ be the electric potential at the position s between the plates.

a) In the non-relativistic limit with laminar flow, write down the Poisson equation in terms of the current density J of the ions, the charge e and the mass m of the ion.

b) For a space-charge dominated ion source, the condition of maximum space-charge shielding is equivalent to $V = 0$ and $dV/ds = 0$ at $s = 0$. What is the maximum current density $J_{\max}$ for a given extraction voltage V_0 at the anode in the space-charge dominated ion source?

c) What is the ratio of the maximum ion current density extracted for singly ionized gold atoms ($A = 79$) versus a proton ion source with the same extraction voltage V_0 in the space-charge dominated limit? Please estimate.