16.522 Space Propulsion
Homework #6

Handed: 4/1/04
Due: 4/8/04

PRELIMINARY DESIGN OF ION ENGINE

We wish to design a 1 N thrust Argon ion engine with a specific impulse of 4500 sec. The acceleration system will consist of extractor, accelerator and decelerator screens, with 1 mm gaps and with an open fraction (to neutrals) of 0.1. The ratio of net to total voltage will be 0.6.

A propellant utilization fraction of 0.8 is desired. As initial estimates, assume $T_e = 3$ eV., $T_i = T_n = 400$K and 5 secondary electrons produced per primary electron. The cylindrical side surface will be equal in area to each end surface of the engine.

Find V_{TOT}, V_{NET}, engine diameter D, ion and neutral particle densities (n_i, n_n), beam current I_b, anode current I_a, cathode current I_c, voltage loss V_{LOSS} and thruster efficiency $\eta = V_{NET}/(V_{NET} + V_{LOSS})$.

HINTS : Assume ions arrive at any surface at a rate $\frac{1}{4} n_i v_B$ per unit area, per second $(v_B = \sqrt{\frac{kT_e}{m_i}})$. Neutrals arrive at $n_n \frac{\overline{c_n}}{4}$ $(\overline{c_n} = \sqrt{\frac{8}{\pi}\frac{kT_n}{m_n}})$ and only a fraction of them equal to the grid open fraction escape. Electrons (both primary and secondary) are lost to the anode only, and they carry with them an energy $2kT_e$ per electron. Work is expended in creating ions ($V_{ioniz.} = 15.8$ Volt for Argon), creating excited atoms which decay by radiation (assume another eV_i per created ion) and heating up electrons, plus, of course, in accelerating the beam. Use an energy balance with these terms to figure out V_{LOSS}.