(3.4) Electrostatic ion thruster

Ion thrusters correct either the attitude or the trajectory of satellites.

The force exerted by a thruster is equal to $m'v$, where m' is the mass of propellant ejected per second and v is the exhaust velocity with respect to the thruster.

Figure 3-15 shows a schematic diagram of a thruster that ejects a beam of charged particles. The propellant enters at P and is ionized in S. Electrodes A and B form a lens that accelerates the positive ions. A beam of positive ions exits on the right at a velocity determined by the accelerating voltage V. The ions of mass m carry charges ne, where e is the magnitude of the electronic charge. The current is I. Electrons emitted by the filament F neutralize the beam so as to prevent the satellite from charging up.

(a) Show that the thrust is given by $F = I[2Vm/(ne)]^{1/2}$.

(b) What is the value of F for a 0.1-ampere beam of protons when $V = 50$ kilovolts?

(c) If P is the power IV spent in accelerating the particles, show that

$$F = (2Pm')^{1/2} = \frac{2P}{v} = P\left(\frac{2m}{neV}\right)^{1/2}.$$

Thus, for given values of P and m', the thrust is independent of the charge-to-mass ratio of the ions. Or, for a given P, F is *inversely* proportional to v. The last expression shows that, *for a given power expenditure P*, it is preferable to use heavy ions carrying a single charge ($n = 1$) and to use as *low* an accelerating voltage V as possible.

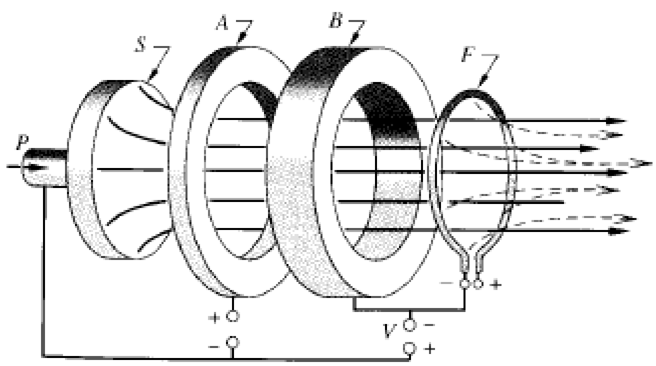

Figure 3-15

(d) If the electron source is turned off, and if the beam current I is 1 ampere, how long will it take the body of the satellite to attain a voltage equal to the accelerating voltage, if V is 50 kilovolts? Assume that the satellite is spherical and that it has a radius of 1 meter. At that point the thruster ceases to operate because the ions follow the satellite.