Space Propulsion Qualifier Exam
January, 2016

SOLVE BOTH PROBLEMS

Problem 1

If you have read "The Martian" or watched the movie, you may have wondered about the method the hero uses to extract water out of hydrazine (leftover from a rocket) to grow his potato crop: He squirts hydrazine under a plastic hood on a bowl lined with catalyst material, then burns the H_2-N_2 gaseous mixture as it exits the hood through a hole.

(a) Comment on the merits or the problems with this method as used on Mars. Are there any purely technical issues here? Is the safety reasonable?

(b) Since the desired end product is water, a simpler alternative could be to burn the hydrazine directly. Propose one or more implementations of this idea, and discuss them from both, technical and safety points of view. Be as quantitative as possible.

Problem 2

One of the most useful properties of a magnetized plasma is the approximate conservation of the so-called "adiabatic invariant"

$$\mu = \frac{1/2 m w_\perp^2}{B}$$

which is constant for a charged particle moving along a slowly varying magnetic field. This property holds even in the presence of a uniform electrostatic field co-linear with the magnetic field.

(a) Show that for a steady field that varies at a rate *dB/dx* along the *x* direction, the particle is subject to a magnetic axial force which, averaged over one gyration, amounts to

$$F_M = -\mu \frac{dB}{dx}$$

Hint: the magnetic force is orthogonal to the particle motion, and so it has a forward component (along the magnetic axis of symmetry) if the magnetic lines are diverging.

(b) Combine with energy conservation to prove the invariance of μ.

(c) How "slowly" should the field vary in *x* for this concept to apply?