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P3_9 Using a Jet Pack to Slow a Human's Descent

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Abstract
The use of a hydrogen peroxide jet pack as a means of slowing down and stopping a human falling through the atmosphere from a terminal velocity of $67ms^{-1}$ to rest, with a deceleration of 1g is investigated. It is estimated that 5 litres of fuel would be required to decelerate a human, an amount easily available with current jet pack technology.

Introduction

A 'jet pack' is a device that enables a user to overcome Earth's gravity and fly by expelling a hot gas as a propellant. The device is typically worn as a backpack. This paper explores the concept of using a jet pack, not as a flying device but as a device to slow the fall of a human, allowing them to land safely.

A Falling Human

A human falling through the atmosphere will experience a downwards force caused by the Earth's gravity. The magnitude of this force is given by

$$F = mg, \quad (1)$$

where m is the mass and g is the gravitational constant, taken to be $9.81ms^{-2}$. The human will also experience a drag force from the Earth's atmosphere which is given by [1]

$$F_d = \frac{1}{2}\rho v^2 C_d A\,, \quad (2)$$

where ρ is the density of the medium, v^2 is the velocity of the body, C_d is the drag coefficient and A is the cross-sectional area of the body. At terminal velocity the drag force will be equal to the gravitational force, by equating (1) and (2) and solving for velocity the terminal velocity can be shown to be

$$v_t = \sqrt{\frac{2mg}{\rho A C_d}}\,. \quad (3)$$

Current Jet Pack Technology

Commercially available jet packs such as those made by Jet Pack International use hydrogen peroxide as a monopropellant. The 'Jet Pack International H202' model weighs 31.5kg and can hold 26 litres of hydrogen peroxide [2].

Monopropellant gases typically have specific impulses (a measure of the impulse per unit amount of propellant used) of 160-190Ns kg^{-1} [3] and a density of 1440kg m^{-3}[4].

Calculating the Amount of Propellant

Assuming that the falling human weighs 75kg and is wearing the H202 jet pack and can be modelled as a sphere of radius 0.4m and so has a drag coefficient of 0.5 [1], with density taken to be the density of air at one atmosphere of pressure. The combined mass is 105.5kg and so the terminal velocity of the human would be $67ms^{-1}$. It should be noted that modelling the jetpack and the wearer as a sphere provides an upper limit on the terminal velocity; a more accurate description would be modelling the jetpack and wearer as two cuboids. Large amounts of acceleration/deceleration are uncomfortable and dangerous and so only '1g' ($9.81ms^{-2}$) of deceleration should be applied to the human.

The thrust provided by a rocket assuming that there are no losses due to friction is given by [5]

$$F_t = I_{sp}\frac{\Delta m}{\Delta t}g, \quad (5)$$

where I_{sp} is the specific impulse, Δm is the change in propellant mass and Δt is the change in time. At 1g of deceleration it would take a human travelling at $67m^{-1}$, 6.82 seconds to come to a halt. The specific impulse is assumed to be 175 Ns kg^{-1}. The thrust required for 1g deceleration for a mass of 105.5kg is 1035N. The amount of propellant required can then be calculated by solving (5) for the mass and is found to be 4.11kg of hydrogen peroxide or 2.86 litres. This amount of fuel is easily obtainable with current jet pack technology. It should be noted that this calculation is only an estimation because it has assumed that there no change in the drag force and no change in the force required due to the changing mass. The amount of mass expelled is small when compared to the total mass and the deceleration phase only takes 6.82 seconds so ignoring these factors should not significantly change the result.

Conclusion

Current jet pack technology has been shown to be sufficient in slowing down a human that is falling with only a small amount of propellant required. A jet pack costs approximately $150,000 much more than a conventional parachute that is very reliable. There is no particular need to use a jet pack as a parachute.

References

[1] G.K. Batchelor *An Introduction to Fluid Dynamics* (Cambridge University Press, 1967) p. 52

[2] http://www.jetpackinternational.com/
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[3]http://history.nasa.gov/conghand/propelnt.htm
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[4]http://www.chm.bris.ac.uk/motm/h2o2/h2o2h.htm
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[5] G.P. Sutton, O. Biblarz *Rocket Propulsion Elements* (Wiley, 7th edition, 2000) p. 87.