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P1_1 The Chief's Downfall

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Abstract

In this paper, we calculate an estimate of the Master Chief's vertical velocity with varying altitude and atmospheric density as he falls towards Earth in the game Halo 3. We plot the velocity over the fall as a function of time and estimate the final velocity to be 69.6ms^{-1}.

Introduction

In the game Halo 3, the Master Chief exits a crashing spacecraft and plummets towards Earth. However, he remains unharmed due to the Spartan armour he is wearing. This armour makes the descent different to other human descents that have been covered in this Journal, as it gives the Master Chief a mass of 451.3kg. This mass will have a much greater effect on his final velocity as his surface area is much closer to that of a human. We calculate his vertical velocity upon impact and compare this with that of a skydiver as well as plotting velocity with increasing time.

Theory

The net vertical force upon the Master Chief is found by resolving the forces acting upon him: gravity and drag. The gravity component is found by the equation $Fg = mg$ where $m = 451.3$kg, the Master Chief's mass [1], and $g = -9.81$ms^{-2} , the acceleration due to gravity. The drag force varies with the velocity, as in the drag equation $F_D = \frac{1}{2}\rho(z)u^2C_DA$ [2] where C_D is the drag coefficient. A human body face-on has a drag coefficient of between 1.00 and 1.30 [3]. Since the Master Chief would presumably assume a spread-eagled position to maximise his drag, we took the larger of these values, so in this model, $C_D = 1.30$. We approximate the surface area A of the Master Chief facing the ground to a rectangle of the same height and width. The Master Chief has a height of $h = 2.18$m [1], and assuming he has roughly vitruvian proportions, he will have a width of $w = 0.545$m. The area is then found from $A = hw = 1.19$m^2 . [4]

To find the velocity u we assume that his initial vertical velocity is $u_0 = 0$. We programmed an iterative process to find u using the equation $u_t = u_{t-0.001} + at$ where a is the resultant acceleration found by $a = \frac{F_g+F_D}{m}$, and $t = 0.001$s is the interval between each iteration. While this simplifies the overall process, the interval is small enough to make little difference.

The air density $\rho(z)$ varies with altitude. We use an equation estimating the relationship between the two, $\rho(z) = \rho(0)e^{\frac{z}{H}}$ [5] where $\rho(0) = 1.2250$kgm^{-3}, the density of air at sea level [6], and $H = 7.4$km is the scale height.

The Master Chief fell at least 2km [7], so the initial altitude is $z(0) = 2000$m. The new altitude with each iteration is calculated using the equation, $z(t) = z(t - 0.001) + ut - 0.5at^2$.

During each iteration density was calculated first, then the acceleration. The new velocity was found with these values, before calculating the altitude. This process was repeated in Python until the altitude reached $z(t) = 0$.

Results

It was found that, at time $t = 32.4$s, the Master Chief hits the ground with a velocity of $u = 69.6\text{ms}^{-1}$.

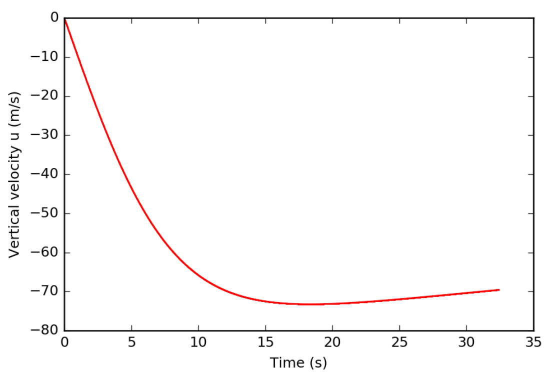

Figure 1: The vertical velocity of the Master Chief with varying time. Note that the velocity is negative, as the positive direction is defined as the direction of the altitude.

Discussion

From Figure 1, it can be seen that the Master Chief stops accelerating after a time of approximately 15 seconds, and reaches terminal velocity at approximately 17 seconds into his descent, at which point he is approximately 1km from the ground. He then decelerates, but this is to be expected, as he is falling through denser air as he approaches the ground. This makes the calculation distinct from similar calculations made in the journal by Rogerson et al [8], since their model considers distances of order 10^2m, where air resistance is negligible, whereas here the air resistance is significant.

The vertical velocity $u = 69.6\text{ms}^{-1}$ with which the Master Chief hits the ground is far greater than the terminal velocity of a skydiver, $u = 56\text{ms}^{-1}$ [9]. The Master Chief's mass is around 6 times a normal human's. Since the drag force is proportional to u^2 , we can expect his terminal velocity to increase by a smaller factor, so this estimate is reasonable. While this kind of impact would almost certainly kill a person under normal circumstances, the Master Chief is using technology from 2552 AD. We cannot project how well he would have been protected.

Conclusion

We found that the Master Chief reaches terminal velocity during his fall, impacting the ground with a vertical velocity of $u = 69.6\text{ms}^{-1}$, an impact most humans are unlikely to survive, but which the Master Chief evidently can. A follow-up investigation could estimate the validity of the cratering shown in the game given the impact velocity found herein.

References

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