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P5_8 Out of World Experience

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Abstract

We investigate the potential for someone skydiving on other worlds if they had protection against the hostile temperatures and pressures. We find that there are 4 astronomical bodies in the solar system that could potentially be suitable for skydiving with notable examples being Titan where you could glide to safety with just an umbrella (diameter > 88cm) and Mars where you would need a parachute the size of a swimming pool (> 24m) in order to survive.

Introduction

With an increasingly large interest in colonising other planets in the solar system, it seems only fitting that we investigate ways we could entertain ourselves on other worlds. Skydiving requires a delicate balance between the force of gravity pulling the diver down and the force of drag resisting their motion and we seek to investigate this balance in this paper. We will assume that both the diver and the parachute are resistant to the extreme temperatures and pressures applied in such hostile environments, that the weather on the planet has no effect on the dive and that the density of the atmosphere and gravitational pull of the body change at a negligible rate (which can be assumed as skydiving is a near-surface activity and changes in gravitational pull and atmosphere become more significant over longer distances).

Analysis

When skydiving, the drag force of the atmosphere on the skydiver is given by

$$F_D = (1/2)\rho v^2 C_D A \tag{1}$$

where ρ is the atmospheric density, v is the velocity of the skydiver, C_D is the drag coefficient (1.2 for a human body [1]) and A is the cross-sectional area of the skydiver (0.15 for a human body using shoulder width as a radius [2]). As the velocity increases, the drag force increases until the skydiver reaches terminal velocity where their weight is equal to the drag force so there is no net force on them. Equating these two forces gives us the terminal velocity

$$v_t = \sqrt{(2mg/\rho A C_D)}, \tag{2}$$

where m is the total mass of the skydiver which we will say is 76 kg from the combined mass of an average human being [3] and a typical parachute [4], and g is the acceleration due to gravity. At some point the diver opens the parachute and accelerates upwards until a lower, safe terminal velocity is reached. Only 2 factors change v_t at this point: C_D which becomes 1.75 for a parachute and arguably the most important variable, A. Knowing ρ near the surface of a planet, the specific value for g of a planet and the safe speed with which a skydiver can hit the ground (6ms^{-1} [4]), we can calculate the cross-sectional area of the parachute required as shown in Table 1. As most of these values are kept constant in this specific case, we can calculate A as a ratio of g to ρ where $A \approx 2.41g/\rho$. Therefore A increases with increased g/ρ as is reflected by the results of Table 1.

Object	g (ms^{-2})	ρ (kgm^{-3})	v_t before parachute opens (ms^{-1})	g/ρ ($m^4kg^{-1}s^{-2}$)	Calculated A of parachute (m^2)
Venus	8.87	65.00	10.70	0.14	0.33
Earth	9.81	1.23	82.13	7.98	19.38
Mars	3.72	0.02	395.00	186	448.26
Titan	1.35	5.37	14.52	0.25	0.61

Table 1: Calculated terminal velocities reached by a human falling on various astronomical objects and the cross-sectional areas of parachutes required for skydiving safely on these objects (as determined by the ratio of g/ρ). [4]

It should be noted that only 4 astronomical bodies were found suitable for skydiving as others either have a lack of atmosphere (and therefore drag force) or they are gas giants with no definable surface; just a dense gas that gradually becomes a liquid closer to the core of the planet. Using the results from Table 1, the standard relation $t = \int(1/a)dv$ and basic integration, we can also work out the time taken from the moment the parachute is opened until the safe terminal velocity is reached from

$$t = \frac{\sqrt{m}}{2\sqrt{gk}} ln\left(\frac{\sqrt{gm}+\sqrt{k}v}{\sqrt{gm}-\sqrt{k}v}\right) \tag{3}$$

where k is $(1/2)\rho v C_D A$ from the drag force of eq. (1). And from eq. (3), a velocity-time graph can be created as shown by Figure 1. Figure 1 demonstrates a variety of times taken to reach terminal velocity once a parachute is opened as a result of different values of g, ρ and the initial value of v_t where Earth and Mars have a much larger change in pre- and post-parachute v_t than Venus and Titan as indicated by their much steeper slopes.

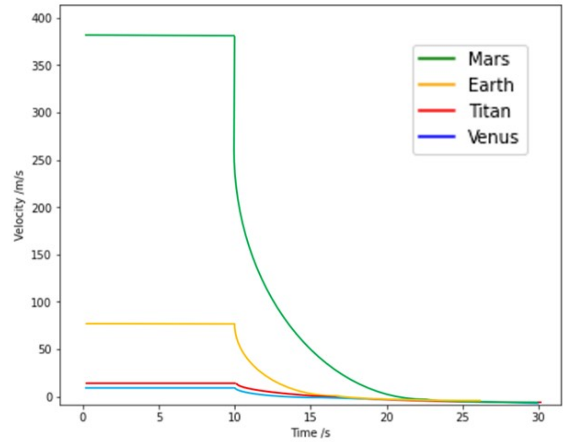

Figure 1: A velocity-time graph of a skydiver travelling at terminal velocity on various astronomical bodies, opening a parachute of size A (from Table 1) after 10 s and reaching a new safe terminal velocity of 6 ms^{-1}.

Conclusion

Although the dangerous conditions on the surfaces of other planets and moons prevent us from being able to skydive on them, it is interesting to see the drastic effect gravity and atmospheric density have on a falling object with the most notable results being the tiny cross-sectional area required from a parachute on Titan (about the size of an umbrella) and the large size of the parachute needed for Mars where although it has less gravity, this is significantly outweighed by its thin atmosphere creating a lack of drag resistance. We find that with an increased ratio of gravitational pull to atmospheric density, an increased parachute size is required and terminal velocity is reached in a greater time.

References

[1] `https://en.wikipedia.org/wiki/Drag_coefficient` [Accessed 25 October 2020]

[2] `https://www.health.com/shoulder-size` [Accessed 25 October 2020]

[3] `https://en.wikipedia.org/wiki/Human_body_weight` [Accessed 26 October 2020]

[4] `https://www.grc.nasa.gov` [Accessed 27 October 2020]