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A1_3 Paragliding through Hyrule

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Abstract

'The Legend of Zelda: Breath of the Wild' is an open world video game where the character Link can use a paraglider to soar over the fictional world of Hyrule. After calculating the terminal velocity of Link's vertical fall speed with the paraglider open, we found that the air density at sea level is approximately 265 kg m^{-3}, which is 216 times greater than the Earth's. Additionally the atmospheric pressure was found to be 22.3 MPa. We compared this pressure to that of a diver on Earth and found that this atmospheric pressure is greater than the maximum depth any scuba diver on Earth has reached.

Introduction

The world of Hyrule in the popular video game, 'The Legend of Zelda: Breath of the Wild', is vast and open, inviting players to explore every secret and climb every mountain. The easiest way down from these immense heights is to jump off, using the paraglider to safely land back on the ground. In this paper we estimate how dense the atmosphere of Hyrule must be to give Link (our protagonist) a slow terminal velocity with such a small paraglider.

Theory

Sky divers reach terminal velocity when the drag force of air resistance is equal to their weight, so there is no longer a resultant force causing acceleration. This velocity v is given by

$$v = \sqrt{\frac{2mg}{\rho_a C_d A}} \tag{1}$$

where m is the mass of the skydiver, g is the acceleration due to gravity, ρ_a is the density of the air, C_d is the drag coefficient and A is the surface area of the parachute, or in this case paraglider. The paraglider is not flat like a traditional paraglider, but more like a miniature parachute. We can therefore model it as a parachute.

After finding Link's terminal velocity we then compared how the atmospheric pressure P of Hyrule compares with the Earth, and the depth h a scuba diver on Earth must reach to experience the same conditions using the following equations:

$$P = \frac{\rho_w RT}{M} \tag{2}$$

$$h = \frac{P}{\rho g} \tag{3}$$

where ρ_w is the density of seawater, R is the ideal gas constant, T is the temperature, M is the molar mass, and g is the acceleration due to gravity.

Method

There is a mini-game where the player can jump from the top of a high tower and glide to the bottom. The distance is given in metres. Normally, a player would get as far away from the tower as possible, using the paraglider. However, horizontal velocity would introduce lift. To avoid this we participated in the mini-game, but fell vertically downwards with the parachute open, without any horizontal component. Therefore we were able to use equation (1) to find Link's terminal velocity.

By recording footage of Link falling down the tower and analysing frame by frame we deduced that it takes 2-4 frames until Link appears to stop accelerating. Since the game runs at 30 frames per second [1], we will consider that the time Link spends accelerating to reach v is negligible.

Results

The tower is approximately 70 m tall and with the paraglider open it takes Link around 22 s to fall to the bottom. We found that v is approximately 3.2 m s^{-1}. We modelled the paraglider as a hollow semi-sphere. This gave us a value for C_{d} as 1.42 [2]. We estimated its surface area to be 1 m^2. Assuming that Link has a mass of an average male (70 kg) [3] and that the gravitational field strength of Hyrule is 27.5 m s^{-2} [4] we rearranged equation (1) to find ρ_a. We calculated ρ_a to have a value of almost 265 kg m^{-3}.

We used this to estimate the air pressure at sea level by assuming the atmosphere acts as an ideal gas using equation (2). R is equal to 8.314 J K^{-1} mol^{-1}. Pausing the game brings up a map of Hyrule with the temperature at the corner of the screen. The in-game temperature was 20°C at the time the experiment was conducted, so $T \approx$ 293 K. We assumed that Hyrule has the same atmospheric composition as the Earth's, giving M a value of 0.029 kg mol^{-1} for dry air [5]. We found the air pressure to be approximately 22.3 MPa.

For comparison, we can rearrange equation (1) to find the area of a parachute that a skydiver on Earth would require in order to fall at a terminal velocity of 3.2 m s^{-1}. Using the same values as before and that the density of Earth's atmosphere at sea level is 1.225 kg m^{-3} and that g is equal to 9.81 m s^{-2}, we find that $A \approx 77$ m^2.

We can also compare the air pressure of Hyrule to water pressure on Earth that a scuba diver experiences while diving. The depth can be found using equation (3), under the assumption that ρ_w is equal to 1030 kg m^{-3} for seawater [6]. This gives the equivalent depth dived on Earth as approximately 2.2 km.

Discussion

The density of Hyrule's atmosphere was found to be unsurprisingly large, given that Link appears to fall very slowly as if through a viscous fluid. It is more dense than the Earth's atmosphere by a factor of around 216, since ρ_a on Earth is 1.225 kg m^{-3}. This suggests that everyday life on Hyrule is more physically taxing than on Earth since a thicker atmosphere would require more work done to overcome air resistance.

Additionally, since the deepest scuba dive recorded on Earth reached a depth of 332 m [7] Hyrule's air pressure would equate to over six times the pressure a human can endure, highlighting the resilience of Hylians to high pressures.

Conclusion

Using data we gathered from the game we have estimated the atmospheric density and pressure of Hyrule and found the values to be much greater than those of Earth: 265 kg m^{-3} and 22.3 MPa respectively. For future improvements we suggest modelling the paraglider more accurately than a hollow semi-sphere.

References

[1] https://bit.ly/2PGmsQ3 [Accessed 01/11/2019]

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