A1_3 Paragliding through Hyrule

M. McKee, A. Goodwin, L. Horton, L. James, C. Mander

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

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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

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

where $m$ is the mass of the skydiver, $g$ is the acceleration due to gravity, $\rho_a$ 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:

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

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

where $\rho_w$ 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
take 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 rear-
arranged equation (1) to find \( \rho_a \). We calculated \( \rho_a \)
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 \( T \approx
293 \text{ K} \). 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 atmo-
sphere at sea level is 1.225 kg m\(^{-3}\) and that \( g \) is
equal to 9.81 m s\(^{-2}\), we find that \( A \approx 77 \text{ m}^2 \).

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

**Discussion**
The density of Hyrule’s atmosphere was found
to be unsurprisingly large, given that Link ap-
pears to fall very slowly as if through a viscous
fluid. It is more dense than the Earth’s atmos-
phere by a factor of around 216, since \( \rho_a \) on
Earth is 1.225 kg m\(^{-3}\). This suggests that ev-
eryday life on Hyrule is more physically taxing
than on Earth since a thicker atmosphere would
require more work done to overcome air resis-
tance.

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, high-
lighting the resilience of Hylians to high pres-
sures.

**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**