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A4_5 Ground Control to Major Steven

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Abstract

We investigated the resultant velocity that Steven from *Steven Universe* would be accelerated to due to an explosive decompression within a "Moon base", and if his velocity would cause him to be ejected out into the solar system. Using fluid dynamics and the conservation of momentum, we found Steven's outward velocity to be 96% smaller than the escape velocity and hence would not escape the gravitational influence of the Moon.

Introduction

In the episode of *Steven Universe: Back to the Moon* [1], Steven Universe (a 14 year old boy who goes on space related adventures) is thrown out into space when the main door of the "Moon base" is opened. If we assumed that the door of the "Moon base" is blown out instead, as shown in Figure 1, would we still expect Steven to be ejected out into the solar system?

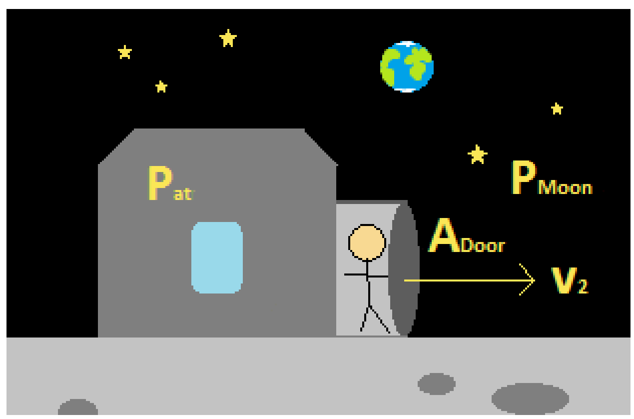

Figure 1: The visual representation of Steven being ejected out from the "Moon Base" (Not to scale).

Theory

As shown in Figure 1, we suggest Steven's position before explosive decompression of the "Moon base" door would be in front of the central point of the door.

When the "Moon base" door is blown out, it produces a valve for the air to escape from with a velocity of v_2. This is due to the difference in pressures inside and outside the base [2]. To find this air flow velocity we used Equation 1 [2], on the assumption that air inside the "Moon Base" [2] and the Moon's atmosphere are incompressible.

$$\frac{P_{at}}{\rho_{at}} + \frac{{v_1}^2}{2} + g_m Z = \frac{P_{moon}}{\rho_{moon}} + \frac{{v_2}^2}{2} + g_m Z \quad (1)$$

where P_{at} is the pressure of the atmosphere held within the base assuming it to be equal to atmospheric pressure on Earth and P_{moon} is the pressure of the atmosphere on the Moon. ρ_{at} and ρ_{moon} are the atmospheric densities at Earth and on the Moon respectively. v_1 is the velocity of the air flow within the "Moon base" and v_2 is the air flow velocity out from the extended door. Lastly g_m is the Moon's gravity and Z is the height above the Moon's surface.

Equation 1 can then be simplified, if we take the Moon's atmospheric pressure to be 0 (approximately 3.0×10^{-10} Pa [3]) when compared to the atmospheric density of the Moon. v_1 is also assumed to be 0 as there is no net flow within the "Moon base" due to the containment of the base's air prior to the loss of the door. Lastly, Z on both sides is assumed to be the same, as the air flow occurs at the same height. We then rearranged Equation 1 to find the air flow velocity v_2.

$$v_2 = \sqrt{\frac{2P_{at}}{\rho_{at}}} \tag{2}$$

From Equation 2, we assume that the flow of air is laminar and so the escaped air particles move parallel to the direction of flow [4].

Following this, if we consider that Steven acts as a blockage to the air flow out from the base, we assume that there is a conservation of horizontal momentum between the particles of air and Steven, where the collisions are elastic. Hence Steven's velocity can be found with Equation 4 [2]. Ratio R is used to estimate the percentage of atmospheric mass that collides with Steven's surface area A_S, when escaping through the surface area of the blown out door A_{door}.

$$R = \frac{A_S}{A_{door}} \tag{3}$$

$$m_S v_S = R V_{door} \rho_{at} v_2 \tag{4}$$

where v_S is Steven's velocity due to the elastic collision between the air and Steven's surface area. V_{door} is the cylindrical volume of the atmosphere contained within the extended length of the door. The product of V_{door} and ρ_{at} is the mass of the atmosphere m_v contained within the extended door and m_S is the mass of Steven.

For Steven to be ejected, his velocity must be greater than the escape velocity v_e of the Moon so to escape it's gravitational influence. This is shown in Equation 5.

$$v_e \leq \sqrt{\frac{2P_{at}}{\rho_{at}}} \left(\frac{R V_{door} \rho_{at}}{m_S} \right) \tag{5}$$

Discussion

We used Equation 5 to show if v_S is greater than v_e. The variables used for the equation are listed below: v_e is equal to 2380 ms^{-1} [3]; P_{at} is equal to 1.01×10^5 Pa [2]; ρ_{at} is equal to 1.293 kgm^{-3} [2]. To calculate R, A_S is equal to 1.50 m^2 [5] (if Steven's mass m_s is 49 kg [6]) and A_{door}, assuming a circular door surface area, is 1.77 m^2 [7]. R is then equal to 0.85. Finally V_{door} is the product of A_{door} and the width of the extended door (5.50 m) [8] which equals 9.74 m^2.

When all variables have been used in Equation 5, we find Steven's velocity v_S to be 86 ms^{-1}.

Conclusion

Steven would be ejected out of the Moon base with an initial velocity of 86 ms^{-1} which is 96% smaller than the minimal escape velocity from the Moon (2380 ms^{-1}). Therefore, Steven would follow half a parabolic path until he returned to the surface of the Moon. Further investigations should consider when the door acts as a nozzle (when opening up) to find if Steven would be thrown into space instead.

References

[1] `https://youtu.be/Aqo61r-ggv0?t=3m4s` accessed on 2/11/16.

[2] Tipler, P.A. and Mosca, G., *Physics For Scientists and Engineers*, (W. H. Freeman, New York, Sixth Edition, 2008), p. 441, 249, 431 and 424.

[3] `http://go.nasa.gov/1KGeoDj` accessed on 1/11/16.

[4] `http://bit.ly/2fFrqve` accessed on 1/11/16.

[5] `http://bit.ly/2eeMlQW` accessed on 2/11/16.

[6] `http://bit.ly/2fdMs0Y` accessed on 2/11/16.

[7] `http://go.nasa.gov/2eAUdgi` accessed on 2/11/16.

[8] `http://go.nasa.gov/2eoWsFX` accessed on 2/11/16.