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A4_1 Blowing Up Earth

R. Coulson, A. Sier, H. Shehzad, J. Wayman, H. Nuttall

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

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Abstract

In this paper, the time it takes to blow up an beach ball, the size of Earth, on different planets is calculated. It was determined it would take the least amount of time on Mars with a time of 3.139 ± 0.0564 Trillion years. It would take the longest on Venus with a time of 17.89 ± 3.215 Trillion years.

Introduction

The time it takes to blow up an inflatable beach ball can sometimes feel like an eternity. Now imagine this inflatable was the size of the Earth and you were on a different planet. This paper aims to put into perspective how long blowing up a beach ball actually takes. The paper is a theoretical experiment so it is assumed that you can breathe on the planets with larger atmospheric pressure than Earth.

Equations

To begin, Bernoulli's principle was applied to form an equation for the velocity of the air that is expelled from the lungs. This is shown in Eq.(1).

$$P_1 = P_2 + \frac{1}{2}\rho v_2^2 \quad (1)$$

where P_1 is the initial pressure of the air being blown out of the lungs at 103400 Pa [1]. P_2 is the pressure inside the balloon which is 0 Pa, as it has not been inflated yet. ρ is the density of the air on each planet and v_2 is the velocity that the air is expelled at.

$$v_2 = \sqrt{\frac{2P_1}{\rho}} \quad (2)$$

Eq.(2) is the rearrangement of Eq.(1) that was used to find the velocity.

Next the volumetric flow rate was determined so that the amount of air leaving the lungs per second could be used to find the time of blowing all the air from the lungs. This was calculated assuming that a lossless nozzle between the mouth and the beach ball was attached.

$$F_v = v_2 C \quad (3)$$

where F_v is the volumetric flow rate, and C is the cross sectional area of the lungs calculated in Eq.(4.)

$$C = L_w L_T \quad (4)$$

Eq.(4) shows how the cross sectional area was determined using the average width (L_w) and thickness of the lungs (L_T) at values of 0.318 ± 0.028 m and 0.214 ± 0.019 m respectively [2], these were then substituted into Eq.(3).

Next the time (T) was determined by dividing the volume of Earth (which is also the volume of our inflatable) by the volumetric flow rate.

$$T = \frac{V_E}{F_v} \quad (5)$$

where V_E is the volume of Earth, determined by assuming it is perfectly spherical and using the standard formula for the volume of a sphere.

Finally the time taken to blow up the inflatable was determined using Eq.(6)

$$T = \frac{2R}{31536000} \tag{6}$$

where 31536000 is the conversion into years. The time was multiplied by 2 to account for each breath in between blows.

Results

The above process was repeated for each planet using the density of their air at 1 bar for the gas giants (as they have no surface) and the surface density for the others [3]. Mercury was excluded from this study as it's atmosphere is non-existent so there is no air. The graph is logarithmic as there was a large difference in the orders of magnitude and this provides a better representation of the trend. The quoted time frames that will be used in the discussion will be the non-logarithmic ones to get a sense of scale.

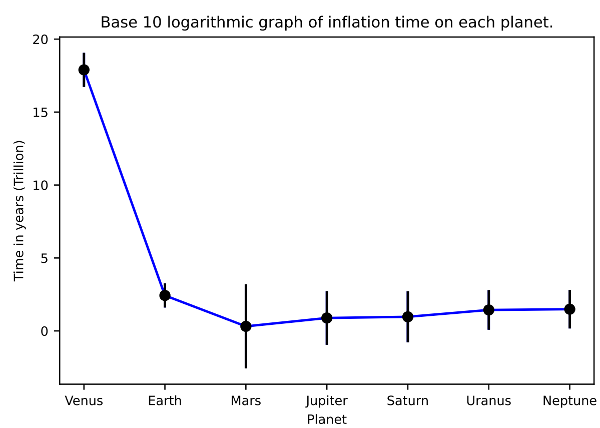

Figure 1: Shows the inflation time on each planet.

Discussion

From Figure [1], the planet on which it would take the least amount of time to blow up the inflatable would be Mars, with a time of 3.14 ± 0.056 Trillion years. This is because it has the smallest air density at 0.02 kg m^{-3}. This means that the velocity that the air leaves the lungs is quicker. Eq.(2) illustrates this inversely proportional relationship between the velocity and density. The faster the velocity, the faster the volumetric flow rate and therefore less time is taken.

On Venus it would take the longest time at 17.89 ± 3.22 Trillion years. This is because its air density (65.00 kg m^{-3}), is a factor of 10^3 larger than most of the other planets densities, relating to a much slower velocity and therefore, more time is taken.

The error bars were calculated by taking the extremes of the lung measurements in [2] and finding the difference with the average value. These bars are quite reasonable which means that the time on each planet could vary a little, however, at the maximum and minimum of the bars, the trend remains similar. This also correlates with the relationships in the equations.

Conclusion

If you wanted to blow up an beach ball the size of earth in the most reasonable time, you should go to Mars. This is because it's air density was the lowest. The worst place to blow up this inflatable would be Venus as its high air density slows down the process. After evaluating these scenarios, suddenly blowing up the average beach ball on Earth does not seem so bad, even if it feels like you are on Venus.

References

[1] `https://bit.ly/3rhDcyW` [Accessed 29 September 2022]

[2] J. S. Yang, J. Kim, S. Choi and K.Health Phys. p487-494, May 2021. doi: 10.1097/HP.0000000000001280.

[3] `http://https://bit.ly/3Eyehil` [Accessed 29 September 2022]