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A1_1 Making a house go 'Up'!

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Abstract

This paper will find that the number of helium balloons required to lift Carl's house is around 4.56×10^5 by using displacement and Archimedes' Principle, therefore requiring around 21 times the amount of helium in Earth's atmosphere. Continuing from this, the suggestion of using 4.23×10^5 hydrogen balloons is made, as the synthesis of hydrogen via electrolysis of water could provide the $4.78 \times 10^4 m^3$ of the gas.

Making a house go 'Up'!

The 2009 classic Pixar animation, Up, follows the journey of Carl and his dream to fly his house to a far away destination using the lift of helium balloons. Once the tears have dried up after Ellie's tragic death, the reality of the situation comes to mind. The physics of this situation will be explored, along with how Carl could make his dreams possible in the real world.

Assumptions and Numerical Constants

Starting with the approximations made in this situation, the house mass used is $54,500$ kg [1] and the balloons are assumed to be spherical with a radius of 0.3 m, giving a volume of 0.113 m^3. The densities of helium and hydrogen are 0.167 kg m^3 [2] and 0.0840 kg m^3 [3] respectively and the volumes of helium and hydrogen in the atmosphere are $5 \times 10^{-4}\%$ [4] and $5 \times 10^{-5}\%$ [5] respectively. The volume of the atmosphere as a whole is assumed to be 4.2×10^9 m^3 [6]. The weight of the balloons themselves are ignored due to the complications with adding more mass, therefore needing more balloons and so on.

Equations and Method

The following equations were used to find that helium balloons would be impractical in the 'Up' scenario. Firstly, the mass (1) and weight (2) of air displaced by one balloon and also the weight of helium/hydrogen in one balloon are found;

$$m = \rho \times v, \tag{1}$$

$$W = m \times g, \tag{2}$$

where m, ρ, v, W and g are mass, density, volume, weight and gravitational field strength (9.81 m s^{-2}) respectively. After finding these weights, the difference was found to be the force upwards per balloon;

$$F_u = W_a - W_b, \tag{3}$$

where F_u, W_a and W_b are the force upwards, weight of air displaced and weight of hydrogen or helium gas in the balloon respectively. The weight of the house is found with the same equation as before (2) and is then divided by the force upwards (3) to get the number of balloons required to balance the upward and downward forces, therefore allowing the house to float. The volume of the total balloons is found by multiplying the volume of a single balloon by the total number of balloons found previously. The actual amount of helium used is 95% [7] of the total gaseous volume, so this is used to get the real volume of helium in balloon gas. The calculated volume of hydrogen is used, however, as it is assumed to be pure.

The volume of helium in Earth's atmosphere was found by working out $5 \times 10^{-4}\%$ of the total atmospheric volume; then the total volume of helium in the balloons is divided by that in the atmosphere to see if there is enough to make this situation viable.

Electrolysis of water

To further this study, the amount of water for electrolysis to produce the volume of hydrogen required can be considered. The chemical equations for this process can be seen below [8].

$$2\,H_2O \longrightarrow O_2 + 4\,H^+ + 4\,e^-$$
$$4\,H^+ + 4\,e^- \longrightarrow 2\,H_2$$
$$2\,H_2O \longrightarrow O_2 + 2\,H_2$$

The volume of water required to produce 1 kg of hydrogen gas is quoted by commercial electrolysis units to be $10 - 11$ m^3 kg^{-1} [8]. Using the upper limit is used to get the most water possibly needed and the volume and density hydrogen quoted earlier, the volume of water needed to fill the hydrogen balloons for lifting the house is around $44,000$ l or 44 m^3, which is around 80 % the volume of water a person uses in a year! Making this route completely plausible, if not wildly risky!

Results

The number of helium balloons needed, at 95 percent helium content, to lift Carl's house is $4.56 \times 10^5 \pm 2280$, which is around 21 times the amount in Earth's atmosphere. The possibility of hydrogen balloons was introduced because hydrogen is a less dense gas, so fewer balloons are needed. Only $4.23\times10^5\pm2115$ hydrogen balloons are required, so $4.78\ \times10^4\ \pm239m^3$ of hydrogen gas is needed. This amount of hydrogen could be synthesised by the electrolysis of $44,000$ l of water. The errors of each of the values are calculates by finding 0.5% of the results.

Conclusion

After finding that helium is not an option to lift the house due to its sparsity in our atmosphere, the route of hydrogen balloons is the next best option. However, there are many issues with using hydrogen, one of which is the extreme flammability. Alongside the possibility of Carl smoking a pipe, much like many old men, the hydrogen approach may be a dangerous one.

References

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