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P2_2 Up Physics

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Abstract

The Disney Pixar motion picture Up, features a scene where a house is lifted from the ground by large number of balloons. We used the assumption that the house weighs 45400 kg (100000 lbs), and was lifted by spherical, helium-filled party balloons each with a radius of 0.152 m. The calculated number of balloons required for the house to be uprooted from concrete foundations with a tensile strength in the range 2.2-4.1 MPa, would be between 5.01x10^9 and 9.33x10^9.

Introduction

In 2009, Disney Pixar released the motion picture film Up, in which a house was elevated from the ground and flown potentially thousands of miles using party balloons. There have been many previous attempts to calculate the number of balloons required to lift a house like the one from the film. However these calculations are purely based on the mass of the house and the buoyancy force from helium balloons, such as the Slate article, How many balloons would it take to lift a house? [1]. In the film there is a scene which depicts the house being torn up from its foundations by the upwards thrust provided from the balloons, so by taking into account the tensile strength of such foundations we have calculated a new value for the number of balloons needed. Assuming these foundations were made from concrete and were left behind after lifting, we calculated the number of balloons required is significantly more. Also, due to the range of tensile strengths possible for a concrete foundation, we will examine the relation between tensile strength and the number of balloons required to lift the house.

Theory

Assuming the balloons to be perfectly spherical vessels then the volume, V, of Helium gas enclosed is given by

$$V = \frac{4}{3}\pi r^3, \tag{1}$$

Where r is the radius of the balloon. As air is much denser than helium at room temperature the balloon will be subject to a buoyancy force, F_b, which is expressed by

$$F_b = (\rho_{air} - \rho_{helium})Vg, \tag{2}$$

Where ρ_{air} and ρ_{helium} are the densities of air and helium respectively. In our calculations we consider the weight of the rubber which makes up the balloon and a single strand of uniformly dense, unbreakable nylon string which would fasten the balloon to the house. The weight, W, of any object with mass, m, in a gravitational field, g, is given by

$$W = mg, \tag{3}$$

By subtracting the weight of both the string and rubber from the maximum upwards buoyant force provided by the helium we calculated the net lift that a singular balloon in this scenario would provide. Next the maximum resistive tensile force, F, provided by the concrete foundations was calculated by

$$F = SA, \tag{4}$$

Where S is the tensile strength of concrete and A is the cross-sectional area of the house, which in this scenario is equal to the floor space of the ground floor. The final value for the number of balloons required to lift the house was found by summing the tensile force of the foundations with the weight of the house and dividing by the buoyancy of a singular balloon.

Results & Discussion

For the foundations we used a range of concrete tensile strengths, which varied between 2.20 MPa and 4.20 MPa [2]. The density of air and helium were taken at 300 K to be 1.16 kgm^{-3} and 0.160 kgm^{-3} respectively [3]. We used a set of kitchen scales to find the mass of a regular uninflated party balloon to be 2.00 g, giving a weight of 0.0200 N. Assuming each balloon has a single 1.00 mm thick, 10.0 m long nylon string. We calculated the weight of each string to be 0.0890 N, given the density of nylon is 1150 kgm^3 [3]. When inflated, the balloon can be assumed to be spherical, with a radius of 0.150 m, which gives a 0.0140 m^3 volume. Considering all of this along with acceleration due to gravity (9.81 ms^{-2}) the lift from a single balloon, is 0.0370 N. The mass of the house is approximately 100,000 lbs, or 45400 kg [1], which gives a weight of 4.45x10^5 N. Assuming the house has two equal sized floors then the surface area of the bottom floor will be half of the total 167 m^2 stated by Slate [1]. The force then required to break the house from the concrete foundation is in the range of 1.84x10^8 N and 3.43x10^8 N. The final value for the number of balloons is between 5.01x10^9 and 9.33x10^9 due to the possible tensile strength of the concrete foundation, as shown in Figure 1. Ultimately, the weight of the house itself is virtually negligible when compared with the force required to break away from the foundation.

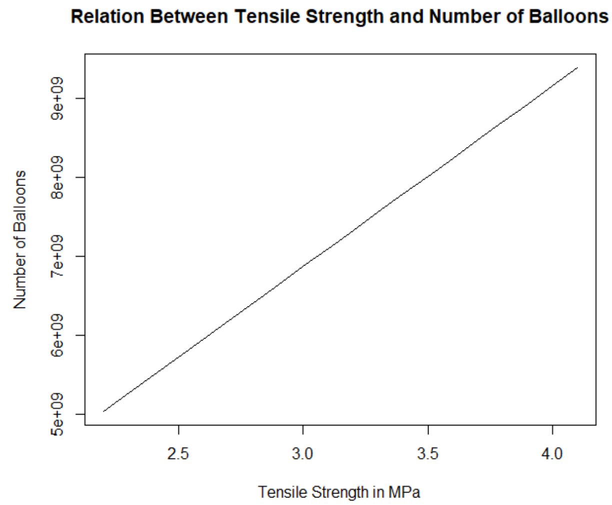

Figure 1: Plot showing the tensile strength of the foundations against the number of balloons

Conclusion

The number of balloons required to lift the house was much larger than that of the one calculated in the Slate article. This shows the significance of the added factor of tearing the house away from its foundations, deeming the force from the weight of the house almost negligible. To improve the result, we could have based the dimensions of the house on a real life house, rather than taking the value used in the article.

References

[1] http://www.slate.com/articles/news_and_politics/explainer/2009/06/how_many_balloons_would_it_take_to_lift_a_house.html [Accessed 3 October 2017]

[2] http://www.concrete.org.uk/fingertips-nuggets.asp?cmd=display&id=525 [Accessed 3 October 2017]

[3] https://physics.info/density/ [Accessed 3 October 2017]