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P1_6 Don't Fire Rockets in Great Glass Elevators

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Abstract

In Roald Dahl's *Charlie and the Great Glass Elevator*, Willy Wonka's Great Glass Elevator, filled with 6 passengers and a bed, launches from Charlie Bucket's house in England and docks to the International Space Station (ISS). In this paper the mass of hydrogen fuel required to launch the elevator is calculated to be 33,325 kg and the feasibility of a glass elevator being launched into space is discussed.

Introduction

At the end of Roald Dahl's book *Charlie and the Chocolate Factory* Willy Wonka, Charlie Bucket and Grandpa Joe break through the roof of the chocolate factory using a 'Great Glass Elevator'. The book ends with them flying across town and landing in Charlie's house. The sequel, *Charlie and the Great Glass Elevator*, follows on from this, describing Charlie, Willy Wonka, Grandpa Joe, Grandpa George, Grandma Georgina and Grandma Josephine in the bed she refuses to leave, all entering the elevator and docking to the International Space Station [1]. By estimating the weights of the passengers in the elevator plus the weight of the glass elevator itself the total mass of the fuel required to launch the elevator into a low Earth orbit can be worked out using the rocket equation.

Theory

Using an approximation for the masses of humans of varying body types [2] and a standard double bed [3], shown in Table 1, the passenger payload of the elevator can be calculated. The masses range from that for a child for Charlie, an average man for Willy Wonka, an ectomorphic man for Charlie's Grandfathers and a small woman for Charlie's Grandmothers. The latter of these masses is due to the continual references in the books to the lack of food the Bucket household have.

Table 1: Average masses for the 'passengers' inside the elevator

Passenger	Mass (kg)
Charlie	32
Willy Wonka	70
Grandpa Joe	47
Grandpa George	47
Grandma Georgina	43
Grandma Josephine (plus bed)	123 (43+80)

Basing the size of the elevator on the standard elevator size for a 630 kg load capacity [4] but scaling the dimensions up due to the size of the bed needed to fit inside the elevator as well as 5 standing adults results in a 2x3x3 m (width x breadth x height) elevator. Standard glass thickness regulations for glass flooring are 38 mm, or 3 layers of 12 mm thick heat strengthened glass [5]. At a mass of 30 kg/m^2 [6] for a 12 mm layer this results in a total floor mass of 540 kg. Regulations for walls and ceilings are slightly more relaxed and a 30 mm thickness of heat strengthened glass is sufficient. At a mass of 25 kg/m^2 [6] for a 10 mm layer, with this multiplied by 4 and added to the mass for a glass ceiling of this thickness gives a mass of 2700 kg. This results in a total glass elevator mass of 3240 kg.

Using the rocket equation, equation (1), the mass of fuel needed to propel the Great Glass Elevator to the height of the ISS can be calculated.

$$ln\Big(\frac{m_0}{m_1}\Big) = \frac{\triangle v}{v_e} \tag{1}$$

Here m_0 is the initial mass, including fuel, m_1 is the final mass of the payload, $\triangle v$ the change in velocity (from stationary) needed to get the elevator into low earth orbit and v_e the exhaust velocity of the fuel.

Results

Adding the passenger mass, of 362 kg, to the glass mass of the elevator, 3240 kg, a total payload mass, m_1, of 3602 kg is found. Assuming hydrogen fuel is used to propel the rocket, v_e of equation (1) equals 4000 m/s [7]. The International Space Station orbits at a height of a low Earth orbit or approximately 400 km. In order to propel a stationary payload to this height the change in velocity must be 7800 m/s [7]. Taking an atmospheric drag of 1500 m/s [7] into account this gives a $\triangle v$ of 9300 m/s. Using these values and equation (1) the mass of rocket fuel needed to propel the Great Glass Elevator to the height of the ISS (after subtracting the value of m_1 from m_0) is 33,235 kg.

Conclusion

In the above calculations the mass of the rocket needed to hold 33,235 kg of hydrogen fuel was not taken into account due to Dahl's book not mentioning any means of propulsion of the elevator other than it being held up by 'skyhooks'. However, comparing the payload mass of 3602 kg to that of that of some of the manned space missions over the years [8], the theoretical launch of the great glass elevator, if considering just its payload mass and the fuel needed to launch it, into space is not unfeasible. The actual mass of fuel required may be slightly higher than calculated due to the elevator launching from 'a town in England' and not the current typical, most efficient, launch sites located on the equator. As the elevator is launched it will experience high levels of acoustic noise, vibration, and transitory G-forces. As it passes through the atmosphere it will also heat up significantly (however not as much as on re-entry). In future papers it may be interesting to consider the durability of glass in space flight and if indeed the elevator and its passengers would be able to survive the journey to the ISS, or more unlikely, re-entry to the Earth's atmosphere.

References

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