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A3_9 Rocket Powered Ski Jump Part 2

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Abstract

In this paper we continue the analysis of a rocket powered MINI attempting a ski jump. Here, we continue the investigation by creating two models, one theoretical and one realistic. Each of these have been plotted in order to visualise the difference in the two. From the maximum velocity previously calculated we estimate the car should be able to travel approximately 440 m horizontally. A more realistic velocity, 45 ms^{-1}, results in a horizontal distance travelled of 170 m.

Introduction

The analysis conducted in this paper follows on from our previous paper A3_7 [1]. Previously, the final velocity of a rocket powered MINI attempting a ski jump, as shown on Top Gear, was found to be 110 ms^{-1} [2]. By using this velocity we calculate how far the car should have travelled and analyse the reasons why this was unsuccessful. This theoretical velocity was then compared to a more realistic model, where we used a lower velocity.

Method

In order to calculate how far the rocket powered MINI would travel, a Python script was written, which was used to plot the trajectory of the car. The forces acting on the car in the y-direction were the weight force due to the car and the lift force from the air. The weight force, F_g, was simply calculated by multiplying the car's mass, 600 kg, by gravity g [3]. The lift force, F_l, was found by using the lift equation,

$$F_l = \frac{\rho}{2} v^2 c_l A \tag{1}$$

where ρ is the density of air, 1.225 kgm^{-3}, v is the velocity of the car, c_l is the lift coefficient of the car, 0.099 and A is the cross sectional area of the car, approximated as 2.5 m^2 [4]. By summing these forces and using Newton's second law, $F = ma$, it was possible to find the acceleration of the car in the y-direction. Next, by using an iterative process with a time step of 0.1 s, it was possible to find the y coordinates of each point in the cars trajectory after leaving the ski jump.

The same process was done in the x-direction. In the x-direction the only force acting on the car was drag due to air resistance. This was found using the drag equation,

$$F_d = \frac{\rho}{2} v^2 c_d A \tag{2}$$

where all the symbols remain the same as in the lift equation except this time the drag coefficient was used as 0.62 [4]. Once again using Newton's second law the x coordinate of the MINI could be found for the whole trajectory, which hence allowed the trajectory of the flight to be plotted.

Findings

By plotting the trajectory of the MINI after leaving the initial ski jump, it was possible to see how far the MINI should have theoretically travelled. We plotted two different graphs, one using the theoretical velocity found from our previous paper, and the second used a more realistic velocity. Figure 1 was created by using the theoretical velocity of 110 ms^{-1}. This shows that according to our calculations the MINI should have cleared the whole ski slope, seen by the green lines in the figures, by a significant distance, landing over 200 m further than the base of the hill. This would have resulted in a total horizontal distance travelled of approximately 440 m.

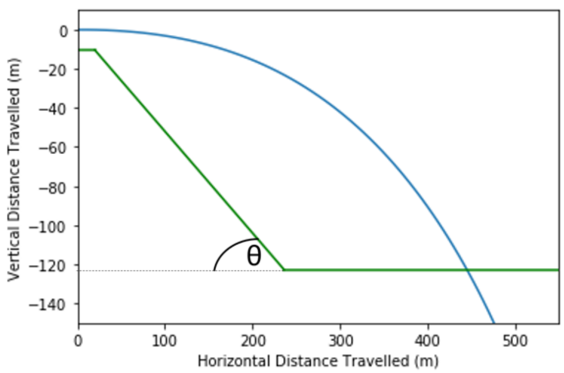

Figure 1: A plot showing the trajectory of the rocket powered MINI - blue line - using a final velocity of 110 ms^{-1}. The green line represents the hill, which we estimate starts 10m below the jump. θ represents the angle of the slope, 27 degrees.

In the actual jump the MINI did not travel far, hence the trajectory in figure 1 did not happen. By watching the clip it is clear the car is not travelling at 110 ms^{-1} [2]. We plotted another trajectory, shown in figure 2, using a lower velocity, which was estimated to be 45 ms^{-1}.

From figure 2 it is clear that this trajectory is more similar to what actually happened. The trajectory in figure 2 shows the MINI travels a horizontal distance of 170 m.

Conclusion

To conclude, we believe that from viewing the

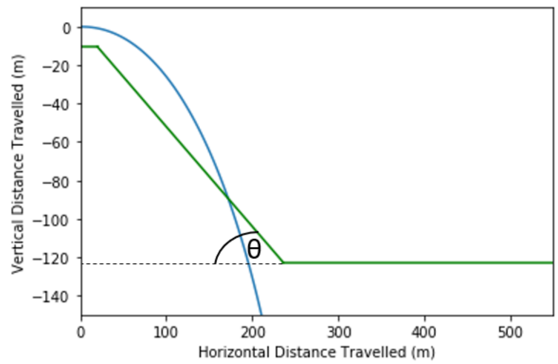

Figure 2: A more realistic trajectory of the rocket powered MINI - blue line - by using a velocity of 45 ms^{-1}.

clip seen in Top Gear and assessing the distance the car travels, the car did not have a final velocity of 110 ms^{-1} [2]. Although the car does not have the upward force that a ski jumper generates by extending their legs, it should still travel much further due to the huge velocity. By reducing the velocity we calculated that the car should travel 170 m. This is still much further than what was seen in Top Gear [2]. This could be due to the unbalanced weight in the car, among other factors. The MINI seems to have more of its weight near the front of the car, causing it to tip downwards into the slope. As this occurs the rockets are still propelling the car, but instead it forces the car into the ground, meaning it does not travel far. To counteract this we suggest more weight at the back of the car, so it tilts back, or cut the rockets out as take off occurs.

References

[1] B. Carlisle, C. Dickens, J. Healings, E. Sampson *A3_7 Rocket Powered Ski Jump*, PST 19, (2020, in press).

[2] ‘Winter Olympics Special’ (2007) *Top Gear*, Series 7 Episode 7. BBC 2, 5th August

[3] `https://tinyurl.com/minimass12` [Accessed 2nd December 2020]

[4] `https://tinyurl.com/coefficient8` [Accessed 2nd December 2020]