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A3_7 Rocket Powered Ski Jump

B. Carlisle, C. Dickens, J. Healings, E. Sampson

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

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Abstract

In this paper we investigate a ski jump done by a rocket powered MINI Cooper, as seen in Top Gear. Over two papers we analyse the physics of the problem and evaluate what went wrong. In this paper we focus on the maximum velocity the car should theoretically reach. We found that the MINI should have reached 110 ms^{-1} at the base of the jump.

Introduction

In Top Gear the hosts decided to test if a rocket powered MINI could travel further than an Olympic ski jumper [1]. In the show the MINI did take off, however, it did not defeat the ski jumper. In this paper we evaluate the physics behind a rocket powered car attempting a ski jump, primarily in this paper we focus on the maximum velocity of the car. A follow up paper will be completed analysing the distance the car should have travelled and consider changes that could be made in order to achieve a jump that could reach a further distance than the olympian.

Method

The aim of this paper was to find the maximum velocity of the MINI, which was done so by initially resolving the forces acting upon it. This was done by subtracting the total upward forces, $F_{friction}$, from the total downward forces, F_{down},

$$F_{total} = F_{down} - F_{friction}. \tag{1}$$

To begin one of the most important values was calculated, the thrust produced. We did this by taking a quote from Jeremy Clarkson where he describes the thrust produced. He states that this car has 'twice as much thrust pound for pound, than an F-15 jet fighter'. As the thrust produced in an F-15 jet is known, it was possible to calculate the thrust in the car. The thrust to weight ratio for the F-15 fighter jet was calculated and multiplied by the mass of the MINI used in order to calculate the thrust for the MINI. This was then converted to Newtons.

After calculating the thrust the only other component of the downward force, $F_{Resultant}$, was calculated by resolving forces. Adding this to the thrust, T, resulted in the total force acting down the ski slope,

$$F_{down} = F_{Resultant} + T. \tag{2}$$

$F_{Resultant}$ was found by taking the downward force, mg, as seen in figure 1, and resolving this in the plane parallel to the slope. This resolved force is $mg \sin\theta$.

After finding the total downward force the opposing force was calculated. This force is the upwards force, $F_{friction}$. This is composed of the coefficient of friction between the skis and the snow, μ, and the resultant normal force, F_{normal}, as seen in equation (3),

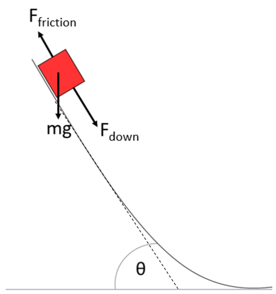

Figure 1: A simple diagram showing the resolved forces of the car on the ski jump.

$$F_{friction} = \mu F_{normal}. \quad (3)$$

The normal force was found by resolving the weight component perpendicular to the slope, which is $mg\cos\theta$. This was then multiplied by the coefficient of friction to find $F_{friction}$.

By returning to equation (1) it was then possible to calculate the total force acting on the car down the slope, F_{total}. By using this force and the known mass of the car in Newton's second law, the acceleration was calculated. This was then used in equation (4),

$$v = u + at, \quad (4)$$

where, v, is the final velocity, u is the initial velocity, a is acceleration and t is the time taken to reach the final velocity.

Findings

Initially the thrust was calculated. To do this the thrust generated in an F-15 fighter jet was used, which was found to be 27,000 pounds of thrust in each of the two engines. Given the total mass of the jet is 45,000 lbs thrust to weight ratio was calculated [2]. This was calculated as approximately 1.2. According to the hosts the car has double this ratio and by multiplying 2.4 by the mass of the car, 600 kg, the car was found to have 3,200 pounds of thrust [3]. This is approximately 14,000 N.

The angle of the slope, labelled θ in figure 1, is approximately 28 degrees [4]. This allowed the calculation of $F_{resultant}$, which was found to be 2,700 N. Adding this to the thrust using equation (2) the total downward force was calculated to be 17,000N.

The angle of the slope also allowed the calculation of the normal force up the plane, which was calculated as 5,200 N. This was then multiplied by the coefficient of friction, μ, 0.01 [5]. This resulted in a total opposing force of only 52 N, meaning a total force of approximately 17,000 N acted on the car down the slope. In this scenario air resistance was treated as negligible.

This force was used in Newton's second law, with the mass of the MINI used, to find the acceleration. This acceleration was 28 ms^{-2}, which was used in equation (4) to find a final velocity of 110 ms^{-1}. This was calculated by using the initial velocity as zero, and the time taken to reach the bottom was estimated to be 4 seconds.

Conclusion

In conclusion the car should have been able to travel a great distance with the thrust that was applied to it. The final velocity of the car at the bottom of the slope should have theoretically been 110 ms^{-1}. However, this large velocity seems unlikely. This, in reality, could have been less due to exaggerated thrust values stated in the episode or other mitigating factors. Next we will calculate how far the car should have travelled and review how this experiment could be improved in order to allow the car to reach a greater distance.

References

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

[2] `https://science.howstuffworks.com/f-15.htm` [Accessed 25th November 2020]

[3] `https://tinyurl.com/minimass12` [Accessed 25th November 2020]

[4] `https://tinyurl.com/lilihammer` [Accessed 25th November 2020]

[5] `https://tinyurl.com/fricoef` [Accessed 25th November 2020]