P4_10 Free Willy!

Smith. J, Brewster. N, Adams. N, Kerr. T.

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

November 15, 2011

Abstract

In the closing scenes of the 1993 movie 'Free Willy', Jesse saves his whale friend Willy from captivity by successfully encouraging him to jump over a marina wall. This paper explores the feasibility of this scene (given that it was in fact computer generated and did not actually occur), by considering the maximum jumping capabilities of an orca whale, and the physical dimensions of the marina wall in question. It was found that Willy would be fully capable of clearing the marina wall if he approached the wall with a jump angle of 50˚. A jump angle of 45˚ would put Willy at risk of striking both Jesse and the marina wall.

Introduction

In the 1993 movie 'Free Willy', Jesse saves his whale friend Willy from captivity by successfully encouraging him to jump over a marina wall. The jump depicted in the film is computer generated and did not actually occur; and so this paper explores the feasibility of the jump by considering the maximum jumping capabilities of an orca whale, and the physical dimensions of the marina wall in question. It should be noted that Willy chose to jump the marina wall at the point where Jesse was stood, increasing the required jump height by the height of Jesse.

Willy

The case which maximises Willy's jump range will be considered. Given that Willy is subject to gravity he will follow a parabolic trajectory as he travels through the air. The range of this trajectory will be a maximum if the launch angle is 45˚ to the horizontal, so a value of 45˚ will be used.

Before this is done however, air resistance will be considered, to establish if it will be a limiting factor on Willy's jumping capabilities. The force due to air resistance, or drag, can be expressed as:

$$F_d = \frac{1}{2}\rho v^2 A C_d, \qquad (1)$$

in which F_d is the force due to drag, ρ is the density of air, taken in this case as 1.3 kgm^{-3}, and C_d is the coefficient of drag, which will be approximated generously as 0.1 given that C_d for a ball is 0.1 [1] and C_d for a Boeing 747 is 0.03 [2]. v in the equation signifies Willy's velocity and will be taken as 48 kmhr^{-1} (equal to 13.3 ms^{-1}) [3]. A is the cross-sectional area of Willy, for which he will be approximated as a cylinder of radius 1 m. Substituting these values into equation (1) yields a drag force of 36.1 N. Given that this value is so small relative to the forces involved (Willy has a weight of approximately 49,000 N [4] and a momentum of approximately 66,500 Kgms^{-1} while travelling at a speed of 13.3 ms^{-1}), it is safe to assume drag can be neglected for the purposes of this paper.

Now, Willy's vertical jump distance can be calculated using the 5th equation of constant acceleration:

$$v^2 = u^2 + 2as. \qquad (2)$$

Rearranging for s and setting v to zero gives:

$$s = u^2/2a. \qquad (3)$$

Substituting u as the vertical component of Willy's initial velocity (13.3 x sin(45)) and a as the acceleration due to gravity (taken as 9.81 ms^{-2}) gives a jump height of 4.50 m.

Willy's horizontal jump distance can be determined using the 3rd equation of motion:

$$s = ut + at^2/2, \qquad (4)$$

once the time t has been determined using a rearrangement of the 6th equation of motion:

$$t = v - u/a, \qquad (5)$$

in which a and v take the same values as before and u is the initial horizontal velocity (13.3 x cos(45)). This yields a jump duration of 0.95 s. Substituting these values into equation (4) gives a horizontal jump distance of 13.82 m.

The Marina Wall

The next step of the analysis is to consider the physical dimensions of the marina wall. This was done using a satellite image of the marina wall, obtained with Google Maps [5].

It can be clearly seen in figure 1 that the width of the marina wall is not uniform; therefore an estimate of the width of the marina wall was made. This was done by drawing a series of 10 equally spaced lines across the wall in the satellite image and recording the length of each of the lines in terms of pixels. The average length of these lines was then compared to the image scale.
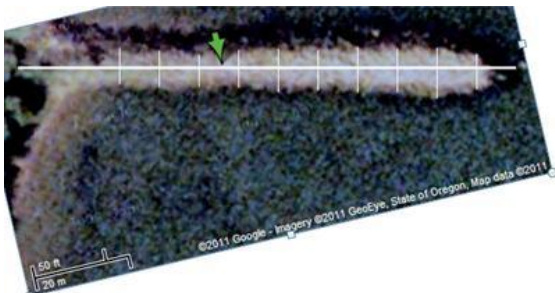

Figure 1: *a satellite image of the marina wall.*

The 20 m scale was determined to be equivalent to 100 pixels and the average width of the marina wall was determined to be 40.6 pixels. Using this conversion the marina wall width was determined to be 8.12 m across.

Figure 2: *the screen shot of the film used to estimate the height of the marina wall* [8]*.*

The height of the wall was estimated in a similar fashion. The actor playing Jesse was born in January 1980 [6] and the film was released in 1993, so the actor is assumed to have an age of 13 years at the time of filming.

By comparison to a child growth chart [7], an estimate of Jesse's height can be made if the assumption is taken that he is of average height for his age. The chart indicates that the average height of a boy of 13 years is 1.56 m.

With this information Jesse's size relative to the wall could be used to make an estimate of the total height of the wall with Jesse upon it. This was done using a screenshot of the film [8]. Jesse's height in the screenshot was 65 pixels, and the average height of the wall was 100 pixels. Using the conversion that 1.56 m = 65 pixels, the total height of the wall with Jesse on top was estimated at 3.96 m.

Conclusion

The estimates presented here indicate that Willy is capable of jumping a distance of 13.82 m, reaching a height of 4.50 m. These figures are greater than the estimates of both the width of the wall, at 8.12 m, and the marina wall height (with Jesse on top), at 3.96 m, by 5.70 m and 0.54 m respectively. This means that Willy would have been capable of jumping the width of the marina wall, but at a jump angle of 45° he would be at risk of not only hitting Jesse mid jump, but also grazing the top of the wall, given that the estimates of Willy's jumping capabilities consider his centre of mass only; they do not account for the fact that Willy is a three dimensional object. If Willy were to jump at a steeper angle of 50°, shifting some of the horizontal clearance to the vertical, he would clear both the required height and width with ease; reaching 5.29 m vertically and 12.98 m horizontally.

References

[1] H.D Young, R.A Freeman, *University Physics*, 9th edition (Addison-Wesley Publishing Company, 1996) p146.

[2]www.aerospaceweb.org/question/aerodyn amics/q0184.shtml accessed 29/11/11

[3]www.enchantedlearning.com/subjects/wh ales/species/Orca.shtml accessed 15/11/11

[4]animals.nationalgeographic.com/animals/ mammals/killer-whale/ accessed 29/11/11

[5]http://sites.google.com/site/wafilmlocatio ns/filmsblog/freewilly1993 accessed 15/11/11

[6]www.imdb.com/name/nm0725284/ accessed 15/11/11

[7]www.mychildhealth.net/wp-content/uploads/2009/06/child-growth-chart.png accessed 15/11/11

[8] *Free Willy,* Warner Bros. Family Entertainment, 1998.