Journal of Special Topics

P4_10 Icarus's Flight

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February 26, 2011

Abstract
The Greek myth of Icarus and Daedalus is challenged by applying physics. The flight dynamics of the wings are explored and it is found that without some form of continual power input, they would not have travelled very far.

Introduction

There is a Greek myth[1] that describes a boy called Icarus and his father, Daedalus, who are held prisoner in a palace on the island of Crete. To escape they fashion wings made of wax and feathers and fly to freedom. However, Icarus gets over-excited with flying and flies "too close to the sun" despite his father's warning. The wax in the wings melts, and he falls to his death. This paper shall point out some of the flaws in the physics of this myth.

The Flight

To model the flight, it is assumed that the wings (2m by 4m each) are approximated as aerofoils. To simplify the model for this paper, it will be assumed that the men will run and jump from the tallest point in the palace (say 100m) and glide until they reach the ground.

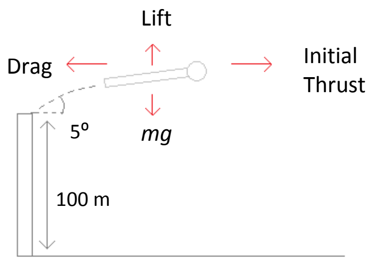

Figure 1. A diagram of the flight, showing the forces acting on the man.

The forces acting on the men are described in Fig. 1. The weight of the men is estimated to be 80kg multiplied with the acceleration due to gravity (9.81 ms^{-2}) and the initial thrust is set to be 400N (calculated by estimating the men to leave the tower with an acceleration of 5 ms^{-2}) but for the rest of the flight there is no force in the positive x-direction. The drag force is given by [2]

$$\boldsymbol{F}_D = \frac{1}{2}\rho \boldsymbol{v}^2 C_D A_1 \qquad (4)$$

where ρ is the density of air (1.25 kgm^{-3} [3]) C_D is the drag coefficient (1.17 [4]) A_1 is the area perpendicular to the direction of travel (estimated to be 0.8 m^2) and $\boldsymbol{v}$ is the velocity of the flier. Similarly, lift is given by [2]

$$\boldsymbol{F}_L = \frac{1}{2}\rho \boldsymbol{v}^2 C_L A_2 \qquad (5)$$

where C_L is the lift coefficient and A_2 is the area of the wings (8 m^2). The lift coefficient is estimated to be around 1 with a 5° angle of attack [5]. With these forces being so essential to the outcome of the flight, constant acceleration cannot be assumed. However, if the system were discretised, then if the individual time steps were small enough (in this case 0.1s) it can be assumed that in each time step there is a constant acceleration and the equations of motion for constant acceleration can be used. By considering the forces in the *x* and *y* directions separately, the net forces acting on the body can be found (by using Eqs. (4), (5), the weight of the body and the initial thrust). Newton's second law then relates the forces to the velocities of the body, and the equations of constant acceleration are used to find the distance travelled. By solving the situation numerically, the outcome of the flight can be found (see Figs. 2 and 3).

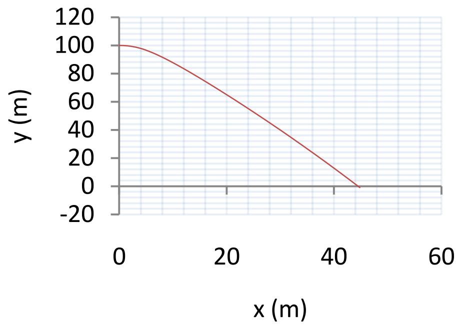

Figure 2. The distance flown by the men. Starting from a 100m tower, they only fly 44m away from it.

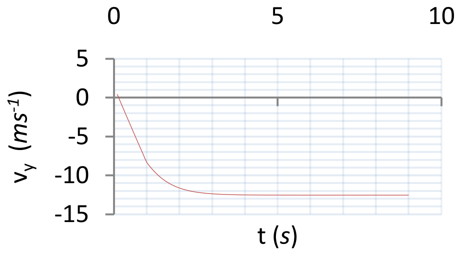

Figure 3. The y-velocity of the flight. It can be seen that the men reach terminal velocity before hitting the ground.

Discussion

Unfortunately, projecting themselves off a 100m tower only gets them 44m away from the tower, so escaping the palace is unlikely and escaping Crete is impossible. A constant source of thrust in the x-direction will improve their distance (keeping a 400N thrust all the way will get them 165m away from the tower, found by running the numerical simulation again with a constant force in the positive x-direction), but the flight-time still has a constraint of 9s due to the forces in the y-direction, so a successful flight almost entirely depends on an additional thrust in the positive y-direction. This is most likely to come in the form of a flapping motion, but birds are only able to give themselves thrust by ensuring their wing area is at a maximum on the downstroke and a minimum on the upstroke – this is clearly not possible with crudely made wing attachments. Another way of achieving more lift is by catching thermal updrafts or other pressure changes in the air, but this is undoubtedly very difficult to control or predict. It is worth noting that the melting temperature of wax (assuming beeswax) is around 60°C [6] so it is unlikely that these updrafts would melt the wax.

The flight only lasts 9 seconds, but within that time the men have managed to reach terminal velocity (see Fig.3). They hit the ground with a y-velocity of 12.5ms^{-1} – without the wing attachments this would be approximately 32.5 ms^{-1} so despite the wings not aiding the escape, they may have saved their lives, or at least improved their chances of landing without major injuries.

Conclusion

It has been found by studying the physical implications of using crudely made wings that the myth is implausible; the flight is most likely too short for them to be able to escape anywhere. The model uses many simplifications, but it is reasonable to assume that the conclusion would not be significantly changed by these.

References

[1]http://www.mythweb.com/encyc/entries/icarus.html *(viewed 03.11)*

[2]G. Woan, *The Cambridge Handbook of Physics Formulas*, Cambridge University Press (2003 Edition)

[3]http://hypertextbook.com/facts/2000/RachelChu.shtml *(viewed 02.11)*

[4]http://www.engineeringtoolbox.com/drag-coefficient-d_627.html *(viewed 02.11)*

[5] Ira H. Abbott, Albert Edward Von Doenhoff, *Theory of wing sections: including a summary of airfoil data,* (Courier Dover Publications, 1959), pp. 472

[6]http://ag.udel.edu/extension/horticulture/pdf/ap/ap-07.pdf *(viewed 03.11)*