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P1_10 Fus Ro Dah

O. East, E. Longstaff, M. Fletcher, C. Li

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

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Abstract

The power of the "Thu'um" is unquestionable within the video game, Skyrim [1]. This paper investigates the possibility of knocking down an opponent using only their voice. It was calculated that the minimum amount of force required to do so is 121.2N, and that an average person can only produce 3.74N.

Introduction

The popular game of Skyrim by Bethesda Game Studios lets players take the role of the Dragonborn [1]. The protagonist possesses magical abilities called the "Thu'um". One in particular is the ability to knock down opponents with the power of just their voice by shouting the words "Fus Ro Dah" [1]. In this paper, we investigate the plausibility of such a feat in an average male using a simple model.

Theory

Firstly consider the target, which was modelled to be a rigid, human sized cuboid. The cuboid is 1.7m high [2], 0.25m wide and 0.25m depth, (estimates for width and depth have been made) with an even distribution of mass of 84kg [2].
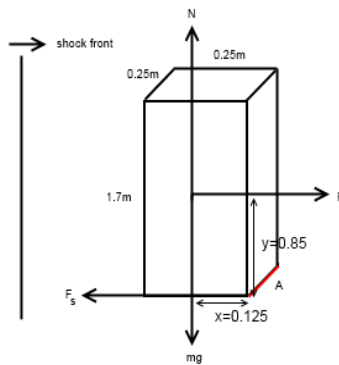

Figure 1. A free body diagram of target modelled as a cuboid.

where N is the normal force, mg is the force due to gravity where m is mass of the cuboid and g is acceleration due to gravity which we assumed to be 9.81 m s^{-2}, F is the force applied, F_s is the force due to static friction and A is the pivot edge.

We assume an even force is applied across the surface, i.e. the force is applied in the centre of the incident face. The cuboid will feel a torque that will cause the whole object to pivot via edge A. We also assume that the force of static friction prevents the cube from sliding and the coefficient of friction μ, to be 0.9 between rubber and dry asphalt [3].

For an average person, their maximum exhaled (tidal) volume is about 0.5 litres [4]. We assume that this volume of air creates a pressure wave that transfers momentum, which exerts a force on the target, and that there is no divergence of the wave or energy loss. To convert the volume to a mass we used air at 30°C with air density at 1.165 kgm^{-3} [5]. We assume that momentum is conserved, and that all momentum is applied to the cuboid surface.

Method and Results

First we considered the minimum force required to tip the cuboid target over. Referring to fig. 1 we can calculate the force of static friction using [6]:

$$F_s = \mu N \qquad (1)$$

where N is the normal force which is equal to the weight (mg) where g is the acceleration due to gravity. From this we obtain a value of $F_s = 742$N. The force applied must not exceed F_s, otherwise the cuboid will slide instead of tip. Now we consider the pivot edge A, where the cuboid will rotate from; consider the equation of torque [7]:

$$\tau = r \times F \qquad (2)$$

where τ is the torque, r is the distance from the pivot and F is the force at the distance.

From the reference of pivot *A*, we can calculate the total torque acting upon that point:

$$\tau_{tot} = \tau_f - \tau_{mg} \qquad (3)$$

where τ_{tot} is the total torque, τ_f is the torque from the applied force and τ_{mg} is the torque force due to gravity. Substituting in τ_f and τ_{mg} and setting $\tau_{tot} = 0$ to find the limiting force, we get:

$$F_{min}y = mgx \qquad (4)$$

Rearrange for F we get:

$$F_{min} = \frac{mgx}{y} \qquad (5)$$

where F_{min} is the minimum required force to tip the cuboid, m is the mass of the cuboid, *x* is half the width and *y* is half the height. From this, we find that $F_{min} = 121.2$N .

We also know that:

$$F = \frac{\Delta p}{\Delta t} \qquad (6)$$

And also:

$$m_g = \rho V \qquad (7)$$

where *F* is the force, *p* is the momentum, *t* is time, m_g is the mass of the gas, ρ is the density and *V* is the volume. Using the values of density and volume and inputting these into eq. 7, the mass of gas exhaled from an average person's lungs is 5.825 x 10^{-4} kg this is the mass of the pressure wave. We then calculate the momentum of the pressure wave using:

$$p = mv \qquad (8)$$

where *v* is the velocity. In this case, the velocity of the pressure wave created is assumed to be v = 320.55 m s^{-1} (sound speed) [8]. Using eq. 8, the momentum of the pressure wave will then be 0.187 kg m s^{-1}.

Referring back to eq. 6, the momentum change, $\Delta p = 2p$ as we assume the air is completely reflected back and assuming that $\Delta t = 0.1\,s$. From this, we substitute in the values calculated into eq. 6, and we find that the force of the pressure wave created by a person is 3.74N.

Returning to F_{min} , rearranging eq. 6 to find the minimum momentum required we find it to be 6.06 kg m s^{-1}. Using eq. 7 and the value of momentum calculated, if the velocity is kept constant, the minimum amount of mass required to be exhaled to tip the cuboid is 18.9 litres. Alternatively if we kept mass constant, then the velocity required would be 10403 m s^{-1} which is roughly 32 Mach (32 times the speed of sound).

Discussion

Realistically, it is impossible for a person to naturally exhale such a large amount of air from their lungs. It is also absolutely ridiculous for a person to create a pressure wave that is 32 times that of the speed of sound, using only their lungs. The result calculated is also the absolute minimum required force to tip the cuboid, with many assumptions.

Conclusion

The power of the "Thu'um" is unfortunately not able to manifest in the real world. Unaided, it is an impossible task to tip an opponent over using just your voice. The amount of force produced by an average human is only 3.1% the required amount of force that is needed. People who wish to achieve such an act may want to stick to the video game.

References

[1]http://www.elderscrolls.com/skyrim accessed on the 6/11/2013.

[2]https://catalogue.ic.nhs.uk/publications/public-health/surveys/heal-surv-eng-2011/HSE2011-Ch10-Adult-obesity.pdf accessed on the 06/11/2013.

[3]http://www.engineeringtoolbox.com/friction-coefficients-d_778.html accessed on the 06/11/2013.

[4]http://hypertextbook.com/facts/2001/LaurenCalabrese.shtml accessed on the 06/11/2013.

[5]http://www.engineeringtoolbox.com/air-density-specific-weight-d_600.html accessed on the 06/11/2013.

[6]http://demonstrations.wolfram.com/EngineeringDynamicsTipOrSlip/ accessed on the 06/11/2013.

[7]P. Tipler, G. Mosca, *Physics with Modern Physics for Scientist and Engineers* (6th ed.), (2008).

[8]http://hyperphysics.phy-astr.gsu.edu/hbase/sound/souspe.html accessed on the 06/11/2013.