Journal of Physics Special Topics
An undergraduate physics journal

A2_6 Falling From Hell (In a Cell)

R. Bradley-Evans, R. Gafur, R. Heath, M. Hough

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

December 2, 2017

Abstract

We take a look at some of the physics involved in the WWE Wrestlemania 32 Hell in a Cell match between The Undertaker and Shane McMahon. By resolving forces and momentum involved in Shane McMahon's fall from the top of the cell and through a table, we calculate the effective impact he feels and compare this to an instantaneous impact (a situation where the table does not break). The reduction in momentum is found to be 943.9 Ns. It is concluded that the table he goes through drastically reduces the impact he would have felt, had it been instantaneous.

Introduction

Professional wrestling is a scripted form of sports entertainment, but there are still many match types and situations which often see wrestlers putting their bodies through high impact manoeuvres. In this paper, we are going to take a look at some of the physics involved in the WWE Wrestlemania 32 Hell in a Cell match that took place between The Undertaker and Shane McMahon. The biggest talking point of the match was when Shane McMahon jumped off the top of the cell and collided with a commentator's table, breaking through it and landing on the ground.

By resolving the forces involved, we can calculate the force of impact (at point 3 on Fig. 1) and the time in which the impact is extended. The impact time is then used to calculate the change in momentum of the collision (at point 4 on Fig. 1). This value is then compared with the instantaneous momentum; in the hypothetical situation that he hit the table without going through it. This comparison allows us to compare the impact of a genuine fall and the effective fall that Shane McMahon actually experiences.

Theory

The physics involved in this scenario requires resolving forces. As Shane McMahon begins his fall from the top of the cell, his initial velocity is 0 ms^{-1}. At this point, the only forces acting upon him are gravity and drag, so the force can be calculated by

$$F_{fall} = m \cdot g - \frac{1}{2} \cdot \rho_{air} \cdot A \cdot C_D \cdot \dot{y}^2, \quad (1)$$

where m is Shane McMahon's mass (104 kg [1]), g is the acceleration due to gravity (9.81 ms^{-2} [2]), ρ_{air} is the density of air (1.293 kgm^{-3} [2]), A is Shane McMahon's cross-sectional area, C_D is the coefficient of drag (1 for an upright human [3]) and $\dot{y}$ is the velocity (for a general case, $\dot{y}$ can also be expressed as $\dot{y}_{fall} = g \cdot t$, assuming negligible air resistance for simplicity). To calculate A, we take Shane McMahon's height of 1.88 m [1] and multiply it by 0.5 m [4] which is an assumption of his frontal body width, estimated by halving the hip size of an average male.

When Shane McMahon collides with the table, the impact is not instantaneous and therefore the effective force he feels is not the same as F_{fall}. In order to compute the effective force, we calculate the change in momentum using

$$p_{actual} = F_{fall} \cdot t_{impact}, \quad (2)$$

where t_{impact} is the time of impact taken from Shane McMahon's collision with the table to landing on the floor.

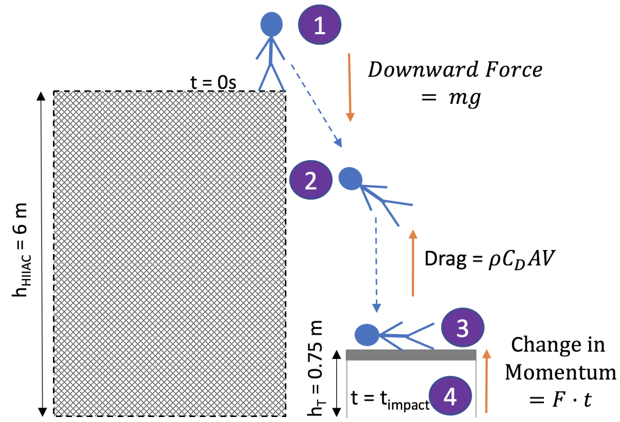

Figure 1: Diagram showing the different stages of Shane McMahon's fall, with annotations of the forces acting.

Results

The point of fall we are focusing on is point 3 in Fig. 1 when Shane McMahon hits the table. At this point of impact, $\dot{y}$ can be expressed as

$$\dot{y}_{impact} = (2 \cdot g \cdot h)^{\frac{1}{2}}. \quad (3)$$

By using Eq. 1 and 3, we find a force of $F_{fall} =$ 957.7 N and an impact velocity of $\dot{y}_{impact} = 10.15$ ms^{-1}. In these calculations, t_{impact} is found by playing the video of the match frame by frame; he falls through the table in approximately 3.5 frames [5]. The standard frame rate used in North American television (WWE is aired on the USA Network) is 29.97 frames per second [6]. Therefore, dividing 3.5 frames by the standard frame rate, we get that the impact time is 0.117 s. This allows us to use Eq. 2 to calculate the total change in momentum to be 111.9 Ns.

The instantaneous change in momentum, p_{inst} can be expressed as

$$p_{inst} = m\Delta v, \quad (4)$$

where Δv is the change in velocity from just before the impact to 0 ms^{-1}, and the calculated value for p_{inst} is found to be 1055.5 Ns.

For all of these calculations, the table properties are condensed into the impact time obtained from the video, and therefore become negligible.

Conclusion

In conclusion, we compare the values for the change in momentum of the actual impact and the change in momentum of an instantaneous impact. This gives us an understanding of the impact physically felt by Shane McMahon, compared to that of an instantaneous force. It is found that there is a change in momentum of $\Delta p = 944$ Ns. By taking the ratio of the two separate momentum values, this can also be expressed as a reduction in effective force of 0.11. Due to all of the above, it can be concluded that the table drastically reduces the impact.

References

[1] http://www.wwe.com/superstars/shane-mcmahon [Accessed 14/11/17]

[2] Paul A.Tipler *Physics for scientists and engineers*, Fourth Edition

[3] https://www.cyclingpowerlab.com/Cycling Aerodynamics.aspx [Accessed 14/11/17]

[4] http://www.arts.ac.uk/media/arts/research/documents/SizeUK-Results-Full.pdf [Accessed 14/11/17]

[5] https://www.youtube.com/watch?v=bWI2l4 ZbdA4 [Accessed 14/11/17]

[6] https://documentation.apple.com/en/finalcut pro/usermanual/index.htmlchapter=D%26 section=4%26tasks=true [Accessed 14/11/17]