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A6_2 The Dark Knight Fights Again: The Physics of Batman v Superman

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Abstract

We analyse the initial physical attacks of Batman and Superman in their fight. The force and stress of each attack are determined using Newtonian mechanics. We determine Batman's punch to have a force $14(\pm11)\%$ of Superman's push, and the punch's stress exerted to be $60(\pm60)\%$ of the opposing attack's stress.

Introduction

In the film 'Batman v Superman: Dawn of Justice', the two heroes engage in combat. In the fight sequence, both characters land physical attacks such as punches and pushes. We consider the first physical attack by Batman on Superman and vice versa, to determine who has the stronger attack and who causes the bigger physical stress.

Theory - Superman's Attack

Superman's initial attack on the mechanised Batman is a push that sends him falling in a projectile path prior to landing on his back. We split this attack into two components (Figure 1): the impulse exerted by Superman and the resultant projectile flight of Batman.

Batman's flight time is calculated with:

$$t_{fall} = \sqrt{\frac{2y}{g}} \tag{1}$$

where the distance from his centre of mass to the ground is $y = 0.97$m [1], and g is the acceleration due to gravity. The horizontal velocity of

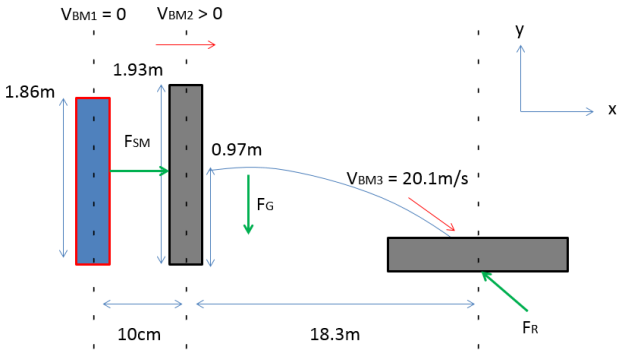

Figure 1: Superman's (blue box) impulsive force and Batman's (black box) fall. Forces are indicated by green arrows, and velocities by red arrows. Only Superman's force, F_{SM}, is considered in this paper. Values from [1] or estimated . Not to scale.

Batman due to Superman's push is:

$$v_{BM2} = \frac{x}{t_{fall}} \tag{2}$$

where $x = 18.3$m is his distance travelled [1]. Batman is initially stationary prior to Superman's push, i.e. $v_{BM1} = 0$, so his change in velocity over the attack is equal to his final hori-

zontal velocity ($\Delta v = v_{BM2}$). The force exerted by Superman, F_{SM}, is calculated by:

$$F_{SM} = \frac{m_{BM}\Delta v}{t_{push}} \tag{3}$$

where $m_{BM} = 218$kg is Batman's mass (including mechanised-suit) [1], and $t_{push} = 0.20(\pm 0.15)$s is the estimated time over which Superman's hand is in contact when pushing. The uncertainty accounts for human reaction time to the event [2]. The stress exerted by Superman, S_{SM}, is:

$$S_{SM} = \frac{F_{SM}}{A_{SM,hand}} \tag{4}$$

where $A_{SM,hand}$ is the area of his hand over which the force F_{SM} is exerted. Superman's hand surface area is assumed to be rectangular of dimensions $20.0(\pm 3.0)$cm $\times$ $8.0(\pm 2.0)$cm, giving $A_{SM,hand} = 1.6 \times 10^{-2}(\pm 4.7 \times 10^{-3})$m^2. The uncertainty is large as the hand area cannot be deduced accurately.

Theory - Batman's Attack

Batman's first physical attack is a punch to Superman's face. Superman's strength is assumed to be reduced to human strength due to his exposure to Kryptonite. Batman's punch force is $F_{BM} = 6316$N [1], which is exerted over his estimated fist area $A_{BM,Fist} = 5.0(\pm 2.5)$cm $\times$ $7.5(\pm 2.5)$cm $= 3.8 \times 10^{-3}(\pm 2.3 \times 10^{-3})$m^2. The large area uncertainty of the gloved-fist accounts for an inability to deduce the thickness of the glove. The stress exerted by Batman's punch, S_{BM}, is calculated by:

$$S_{BM} = \frac{F_{BM}}{A_{BM,fist}}. \tag{5}$$

Results

Superman exerts a force of $F_{SM} = 45(\pm 34)$kN, and the stress on Batman is $S_{SM} = 2.8(\pm 2.3)$MNm^{-2}. The stress exerted by Batman's punch on Superman's face is $S_{BM} = 1.7(\pm 1.0)$MNm^{-2}. The ratio of the forces exerted by the heroes on each other is $R_{Force} = F_{BM}/F_{SM} = 0.14(\pm 0.11)$. Comparing the stress exerted on each other gives $R_{Stress} = S_{BM}/S_{SM} = 0.60(\pm 0.60)$.

Discussion

Batman's punch force is $14(\pm 11)\%$ of Superman's push, suggesting he has nowhere near enough strength to combat his foe. However, Batman exerts a stress $60(\pm 60)\%$ of Superman's stress, indicating he makes up for his lesser strength by impacting over a smaller area than his counterpart. Evidently, Superman has the physical advantage.

However, the error propagation suggests the ratios to be quite unreliable as a result of large uncertainties in estimated quantities. Whilst Superman is always stronger to the limits of the errors, Batman could actually produce the greater stress if the maximum error in the stress ratio is achieved.

Superman is pushing a suit made of a lead-based alloy [1] (Pb Ultimate Tensile Strength (UTS) = 12MNm^{-2} [3]), whilst Batman is hitting bone (UTS = 200MNm^{-2} [3]). The stresses exerted by both heroes do not reach the UTS of their target material, and hence neither is broken. In conclusion, neither attack is strong enough to severely damage their opponent, so the Dark Knight returns and the Man of Steel lives.

References

[1] Batman v Superman: Dawn of Justice: Ultimate Edition - The Might and the Power of a Punch (Blu-Ray Featurette).

[2] `goo.gl/EhBUeL` accessed on 23 Oct 2016.

[3] P. A. Tipler and G. Mosca, *Physics For Scientists and Engineers* (Academic, New York, 2008), Vol. 6, p. 410.