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The Black Panther suit: The amount of energy absorbed from a collision with a moving car

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Abstract
This paper evaluates Black Panther's vibranium suit, a character from a Marvel movie, with regards to the amount of kinetic energy it can absorb upon a collision with an average car travelling at a speed of 70 mph. A value of 734.30 kJ was calculated to be absorbed by the suit. The usefulness of this stored energy is then assessed by contextualizing it in a combat situation against Black Panther's nemesis, Erik Killmonger. Using the energy from the collision, Black Panther would be able to throw Erik vertically at a speed of 144.89 ms^{-1} to a height of 1085.92 m with a force of 1353.01 N. To compare the magnitude of force in relation to the real world, the power generated from the throw can support a UK household for 15.50 days.

Introduction
In the Marvel movie, Black Panther [1], a fictitious suit is designed which is extremely durable and indestructible. This is achieved by absorbing the kinetic energy (KE) of a projectile and then redistributing this energy [2], which can then be released in powerful bursts when desired [3].

The Black Panther suit is made of a vibranium micro-weave mesh. Vibranium is a fictional metal used in the Black Panther world and is the reason for the people of Wakanda being extremely scientifically and technologically advanced [2]. This metal is also found in a herb on Wakanda, which is consumed by Black Panther, giving him the enhanced abilities such as strength, speed and reflexes. The vibranium gives the suit its ability to absorb energy, as the particles in this metal absorb the momentum and energy of any incoming projectiles, resulting in the projectile falling off the suit to the ground instead of being rebounded [2].

One of the characters, Shuri, explained how the suit had been "taking bullets and charging it up with kinetic energy" [4]. In this scene T'Challa (Black Panther), is repeatedly hit with bullets whose energy subsequently charge the suit, this energy is then used to flip a car.

This paper investigates how much energy would be absorbed by the suit if Black Panther were hit by a moving car and subsequently how this energy will be used in combat.

How does the suit absorb kinetic energy?
The vibranium in the suit absorbs the KE of the projectile and stores this energy as elastic potential energy (EPE) in the suit [3]. On impact, the vibranium particles in the suit act as nanosized springs in layers that compress and have the ability to store energy as a result [3]. The energy is then released when the nanosprings stretch back to their original shape. The suit would contain thousands of nanosprings, due to the large area, therefore the amount of energy that can be stored in the suit would be increasingly large.

Impact with the car
The crash between the suit and the car is assumed to be a perfect elastic collision, hence momentum will be conserved. No energy loss will occur and all the KE is conserved (the suit absorbs all energy from the moving car). This assumes that there has been no loss of energy as heat or friction during the collision.

The kinetic energy of the car travelling at a speed of 70 mph, with an average mass of 1500 kg [5] is calculated using equation 1.

$$KE = \frac{1}{2}\,mv^2, \quad (1)$$
$$KE = \frac{1}{2} \times 1500 \times 31.29^2 = 734298\,J,$$
$$KE = 734.30\,kJ.$$

Therefore, 734.30 kJ will be absorbed and stored by Black Panther's suit as elastic potential energy (EPE).

How high can Black Panther throw his nemesis?

Black Panther commonly uses absorbed KE in combat. Therefore, to put the above value in context the maximum vertical height at which T'Challa can throw his nemesis, Erik Killmonger, using the energy obtained from the car collision has been calculated. The initial energy of Erik is assumed to be the absorbed KE from the car collision, as he would be thrown with the same amount of KE that has been absorbed and stored as potential energy (PE). Using this, equation 1 is rearranged, and the velocity at which Erik is thrown into the air is calculated using the mass of Michael B Jordan (69 kg) who plays the character in the movie [6].

$$v = \sqrt{\frac{2 \times KE}{m}}, \quad (2)$$
$$v = \sqrt{\frac{2\ \times 734298}{69}} = 145.89\,ms^{-1}.$$

The initial PE at the ground is zero, while the KE at the maximum height would be zero. Therefore, the PE at the maximum height would be the change from initial KE to final KE as shown in equation 4.

$$PE = mgh, \quad (3)$$
$$PE = \partial KE, \quad (4)$$
$$mgh = \partial KE. \quad (5)$$

Rearranging equation 5 [3], the height at which Erik is thrown with the absorbed energy is calculated shown in equation 6.

$$h = \frac{\partial KE}{mg} = \frac{734298}{69 \times 9.8} = 1085.92\,m. \quad (6)$$

Using the absorbed KE from the impact of the car T'Challa will be able to throw Erik 1085.92 m vertically at 144.89 ms^{-1}. These values can also be used to determine the time taken and the required force to throw Erik using equations 7 and 10.

$$speed = \frac{distance}{time}, \quad (7)$$
$$time = \frac{distance}{speed} = \frac{1085.92}{145.89} = 7.44\,s.$$

Thus, Erik is thrown to 1085.92 m vertically in 7.44 s.

$$F = ma, \quad (8)$$
$$a = \frac{\partial v}{t}, \quad (9)$$
$$F = \frac{m\partial v}{t} = \frac{69\ \times 145.89}{7.44} = 1353.01\,N. \quad (10)$$

The total force used to throw Erik 1085.92 m up in the air at the pre-calculated speed is 1353.01 N. However, this does not take into consideration the force and energy generated from T'Challa himself, rather only that produced by the suit. Using this force, the power generated from the energy absorbed can be calculated using equation 11 [7].

$$P = \frac{\partial W}{\partial t} = Fv, \quad (11)$$
$$P = 1353.01 \times 145.89 = 197390.63\,W$$
$$P = 197.39\,kW$$

This is a large amount of power generated from just one collision. To contextualise this magnitude of power UK households can be analysed. The average power to run a household in the UK is approximately 12.73 kWh per day [8], therefore the power generated from the energy absorption of the collision would be enough to sustain an average UK household for 15.50 days.

Conclusion

Black Panther's suit allows him to absorb and store KE, this energy is frequently used in fights. KE gained by the suit, if hit by an average car travelling at 70 mph, was calculated to be 734.30 kJ. The usefulness of this energy in combat was evaluated in terms of the speed and height at which T'Challa could throw his opponent. Erik Killmonger would be vertically thrown at a speed of 144.89 ms^{-1} reaching a height of 1085.92 m. The power generated from this would be about 197.39 kW. For an ordinary human this would be impossible, as Black Panther is fictitious these values seem reasonable.

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